Outdoor Lighting Research

California Outdoor Lighting Standards

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Prepared for:

California Energy Commission

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Overview

Background

Goal

The goal of the project is to conserve energy and reduce electric peak demand through cost effective energy efficiency standards for outdoor lighting. In adopting cost effective energy efficiency standards for outdoor lighting consistent with public health and safety, the California Energy Commission (CEC) anticipates that the standards will also improve the quality of outdoor lighting, e.g., reduce light trespass, excessive illumination, poor uniformity, glare, and poor visibility. However, the proposed standards are justified only on the basis of energy savings and peak electricity consumption.

Outdoor lighting standards are different from the indoor lighting standards of Title 24 in that, for outdoor lighting, the default condition is the natural darkness of the night. These outdoor lighting standards are not intended to set minimum standards of illumination. Their purpose is to set minimum control requirements, maximum allowable power, and minimum efficacy. The recommendations for allowed lighting power are based on current Illuminating Engineering Society of North America (IESNA) recommendations for the quantity and quality of illumination, current industry practices, and efficient sources and practices. The alternative of providing lower illumination at night is always available to any building owner or lighting designer, and should be considered when practical. Indeed, a 2002 baseline survey of current outdoor lighting practice in California suggests that the majority of establishments currently are illuminated at substantially lower levels that the IESNA recommendations.

Scope

Standards are being proposed for:

- Unconditioned buildings.
- Parking lots.
- Building grounds.
- Building entrances and exits.
- Building façades.
- Exterior canopies.
- Outdoor sales.
- Billboards and outdoor signage.
- Public rights of way.

Standards are not being proposed for:

- Traffic signals.
- Sports lighting.
- Illumination of public monuments.
- Lighting for ATMs.
- Decorative gas lighting.
- Lighting for theatrical purposes, including performance, stage, and film and video production.
- Exit signs.
- Lighting that is specifically designated as required by a health or life safety statute, ordinance, or regulation.
- Emergency lighting powered by an emergency source as defined by the California electrical code.

All of the proposed standards will be implemented as part of Title 24, Part 6, except for Measure 9 – Public Right of Way Lighting, which is being recommended as a model standard to be voluntarily adopted by CALTRANS and local jurisdictions.

Rationale

Outdoor lighting consumes a great deal of electricity and can be a significant contribution to peak electric demand, especially when it is improperly controlled. Through legislation adopted in 2001, the CEC has been authorized to establish energy efficiency standards for outdoor lighting.

It is important to note that poorly designed outdoor lighting can result in community and social problems, such as light trespass and light pollution[1], as discussed below.

- Light trespass is unwanted light from a neighboring property. It is a growing concern in many communities, as sources of outdoor lighting have become more intense. Any source of light can create trespass, but complaints are related mostly to sports lighting, billboards, and street lighting. Light trespass is annoying, but it can also be a serious nuisance or even a serious health and safety risk if it adversely affects visibility for other tasks. Light trespass may also be a source of glare, including disabling, discomfort, veiling luminance, and annoyance glare that can also be serious public health and safety risk.
- Light pollution is outdoor lighting that is directed or reflected to the sky. It creates sky glow that reduces the visibility of stars and changes the whole character of the night sky. With sky glow, low clouds appear light in color. Without light pollution, low clouds would appear dark. Light pollution also reduces the effectiveness of observatories located near cities. Satellite photographs at night reveal the outline of the entire continental U.S. and all urban centers are clearly visible.

While light pollution and trespass are important, the proposed standards are justified only from energy savings and peak demand reductions, as directed by statute.

The Legislative Mandate

In response to the California electricity crisis, the California Legislature passed and Governor Davis signed Senate Bill 5X (Statutes of 2001), which requires the CEC to adopt energy efficiency standards for outdoor lighting. SB 5X added the following section to the Public Resources Code:

> *25402.5 (3) (c) The commission shall adopt efficiency standards for outdoor lighting. The standards shall be technologically feasible and cost effective. As used in this subdivision, "outdoor lighting" refers to all electrical lighting that is not subject to standards adopted pursuant to Section 25402, and includes, but is not limited to, street lights, traffic lights, parking lot lighting, and billboard lighting. The commission shall consult with the Department of Transportation (CALTRANS) to ensure that outdoor lighting standards that affect CALTRANS are compatible with the department's policies and standards for safety and illumination levels on state highways.*

Through this project, the CEC intends to develop and adopt lighting standards for many outdoor lighting applications, including all unconditioned areas that are not already subject to existing California standards.

Environmental Impact

No negative environmental impact is associated with the proposed outdoor lighting standards. All the impacts are positive. In addition to saving energy, some of the newer lighting technologies, which are encouraged by the proposed standards, last longer to result in less need for disposal and/or recycling. The standards should also reduce light pollution and trespass. Finally, power plant emissions into the atmosphere will be reduced from reduced electricity consumption.

The Schedule and Public Process

The Commission has targeted July 1, 2003 for adoption of these new California outdoor lighting standards. Those portions of these standards that are adopted in Title 24 are expected to go into effect in conjunction with the 2005 California Building Code, expected to become mandatory in 2005. Between the 2003 adoption date

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[1] Note: The *Advanced Lighting Guidelines* have more information on light trespass (§3.2.4) and light pollution (§3.2.5). The *Advanced Lighting Guidelines* is a publication sponsored by the CEC and others. The document is in its third edition and is available from http://www.newbuildings.org/ and from other sources.

and the 2005 effective date, the CEC anticipates that the California utilities will focus Public Goods Charge-funded programs on providing a transition process for early, voluntary compliance with the new standards.

The CEC encourages the public and interested parties to participate in the process. The recommendations contained in this research report will be considered at a public workshop scheduled for June 18, 2002. Please consult the CEC web site or contact the persons below for more details on the agenda and additional opportunities to participate.

CEC Web site: http://www.energy.ca.gov/outdoor_lighting/.

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The following are major project milestones in 2002. Participants should visit the CEC web site to confirm the dates of workshops after the June 18, 2002 scheduled event.

January 29	The CEC and its contractors had a kickoff meeting to identify possible outdoor lighting measures and to make research assignments.
February 1	The CEC launched its outdoor lighting website and invited the public to suggest outdoor lighting standards and to participate in the process. The project synopsis was posted to the site.
March 27	A public workshop was held in Sacramento to discuss the outdoor lighting standards ideas and to receive comment from all interested parties. The Measure Identification Report was presented at that time.
June 18	A public workshop will be held in Sacramento to discuss the proposed standards contained in this document.
August	A draft standard will be developed, which will incorporate the recommendations developed in this research report, with consideration of input received at the public workshops.

Summary of Proposed Standard

Scope

The 2001 California standards only apply for buildings that are conditioned; that is heated or cooled. As part of the revisions, §100(a) of the standards will be modified to include lighting in unconditioned buildings as well as conditioned buildings. In addition, outdoor lighting renovations will be subject to the same guidelines currently listed in the standards for indoor lighting renovations.

Lighting Efficacy

For nonresidential and high-rise residential buildings and hotels/motels, §130 (c) of the standards requires that lamps rated greater than 100 W have an efficacy of at least 60 lumens per watt, but there are a number of exceptions to the requirement. A key exception is that the requirement is triggered only when exterior lighting is connected to the electric system of a building that is covered by the standards. This section of the standard will be modified so that the efficacy requirement applies to all exterior lighting. In addition, the minimum efficacy requirements will be expanded and modified for some lighting applications, e.g., 70 mean lumens per watt (MLPW) for internally illuminated signs and 55 MLPW for externally illuminated signs.

Unconditioned Buildings

For nonresidential and high-rise residential buildings and hotels/motels, the building energy efficiency standards limit the lighting power that can be installed in interior spaces, but the limits only apply to spaces that are conditioned or semi-conditioned as defined by the standards. The standards do not apply to unconditioned warehouses, unconditioned manufacturing facilities, or other unconditioned spaces. Essentially, the current standards treat these unconditioned interior spaces as outdoor spaces, and exempt them from the lighting power requirements. As part of this project, standards are recommended for unconditioned spaces. See the scope change above for §100(a).

Controls

Automatic controls are already required by the standards to turn off exterior lighting during the day and during other periods of time when it is not needed. This requirement already exists in the standard. §130 (f) requires that all permanently installed exterior lighting powered by the building electrical service be controlled by either a photocell or astronomical time switch. This requirement will remain.

In addition to the automatic control, lighting for parking lots, building entrances, and outdoor sales areas must have a control that is capable of reducing lighting power to 50% of maximum.

Shielding

For most applications, only cutoff luminaires are allowed. Shielding luminaires reduce the lighting that escapes to the night sky and reduce glare. Figure 1 shows the four classes of luminaires that are available. Exceptions are provided to this requirement for some of the lighting applications, such as façade lighting.

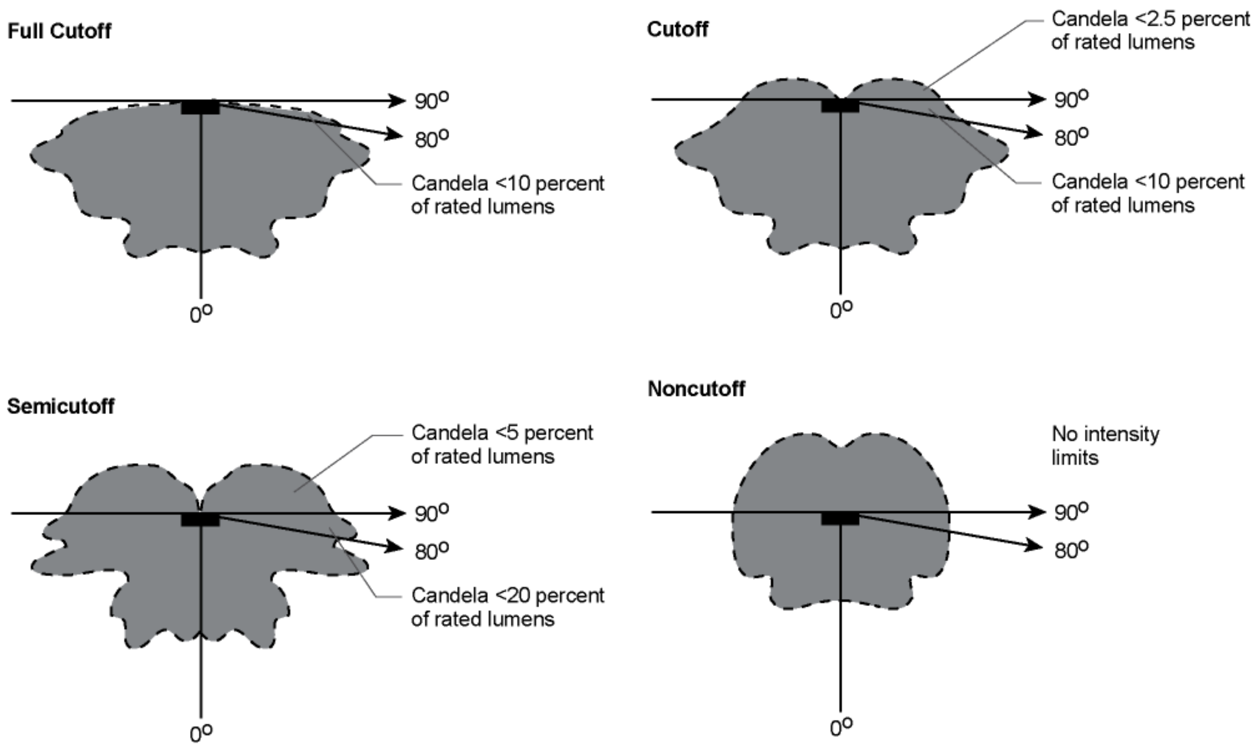

Figure 1 – Cutoff Luminaries

Allowed Lighting Power

The 2001 standards do not have power limits for outdoor lighting. Implementing power requirements is a key feature of this proposal. Allowed power would be expressed as lighting power densities (LPDs), a concept well understood in the code enforcement and compliance community. The allowed lighting power is determined by measuring the area or length of the lighting application and multiplying this times the LPD, which is expressed either in W/ft² or W/ft. Table 1 is a summary of the recommended lighting power allowances. More detail on these recommended values and how they were developed is provided in the technical chapters that follow.

Table 1 – Summary of Lighting Power Allowances (W/ft² unless otherwise noted)

Lighting Application	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Parking Lots	0.04	0.06	0.08	0.20
Building Grounds	0.30	0.35	0.40	0.45
Building Entrances	0.50	0.50	1.00	1.50
Building Facades ✳	Not allowed	0.18	0.35	0.50
Sale Vehicle Lots	Not allowed	0.25	0.50	1.00
Sale Vehicle Lots and Other Outdoor Sales (Street Frontage) ✳	Not allowed	17.5 (W/ft)	35 (W/ft)	70 (W/ft)
Other Outdoor Sales	Not allowed	0.25	0.50	1.00
Internally Illuminated Panel Signs ✳	20 W per face	4.00	6.00	8.00
Externally Illuminated Signs ✳	20 W per face	1.00	2.00	4.00
Public Rights of Way - Expressway	0.036	0.036	0.079	0.054
Public Rights of Way - Major	0.036	0.069	0.084	0.103
Public Rights of Way - Collector	0.036	0.067	0.074	0.077
Public Rights of Way - Local	0.036	0.036	0.049	0.083
Public Rights of Way - Freeway Class A	n. a.	0.043	0.043	0.043
Public Rights of Way - Freeway Class B	n. a.	0.056	0.056	0.056
✳ Indicates that the allowance is a “use-it-or-lose-it” allowance that can only be used for the intended lighting application.				

Area. Using the concept of LPDs requires that the area of the lighting application be defined. For interior spaces, this is rather straightforward. However, for outdoor lighting applications, the area only applies to that portion that is illuminated.

Tradeoffs. Lighting from a parking lot might spill over and light pedestrian walkways. Building façade lighting might partially illuminate building grounds. For these and other reasons[2], it is desirable to be able to determine a lighting power allowance for the entire site and to make tradeoffs between lighting applications. This approach is taken except for those allowances identified in Table 1 as “use-it-or-lose-it.”

These standards would be enforced through the plan checking and field inspection process already employed in Title 24. No new analysis tools are needed for compliance or enforcement, although new charts or forms might be developed to assist inspectors in their duties to verify compliance.

Basic Research Methodology

A fundamental tenant of the research approach is to tailor the lighting standards by lighting zones. Four zones are identified based on surrounding or ambient lighting levels: Lighting Zone (LZ) 1, LZ2, LZ3, and LZ4. The lighting zones are discussed more in the next chapter.

The general approach used to develop each of the proposed lighting standards is described below. Each of these steps is described in more detail for each of the lighting applications.

1. *Design Criteria*. Identify the quantity and quality of light that is needed, based on recommendations of IESNA. The selected design criteria vary with each of the lighting zones. LZ1 needs the least light and LZ4 needs the most. The IESNA recommendations for outdoor lighting are often expressed relative to a choice between two different conditions. For instance, lighting recommendations for gas stations differ between “light surroundings” and “dark surroundings.” The ratio between the two IESNA-recommended lighting levels is usually about 2:1. Based on this observation, the following general rules are used for developing the design criteria for each of the lighting zones:
    a. The highest IESNA lighting recommendation is used for LZ3. This is based on light surroundings.

2 One reason is that Warren Alquist Act requires that the CEC develop performance standards.

  b. The lowest IESNA recommendation is used for LZ2, if there is a low recommendation. If there is not a low recommendation, 50% of the LZ3 recommendation is used for LZ2. This is based on dark surroundings.
  c. For LZ1, either 50% of the LZ2 recommendation or the next lower IESNA recommendation is used. Note that some lighting is not recommended for LZ1, such as outdoor sales.
  d. Finally the LZ4 lighting level is generally assumed to be double the LZ3 value, based on the typical 2:1 ratio between LZ2 and LZ3.

2. *Lighting Equipment*. Determine the appropriate lighting equipment to be used for the application. In general, the most high efficacy sources are assumed. However, the statute requires that the lighting equipment used as the basis of the standard be cost effective. Calculations are provided, when appropriate, to demonstrate this.
3. *Lighting Models*. Develop one or more models that represent the lighting application for which the standard is being developed. The models include assumptions about the geometric characteristics of the lighting application and other features that are relevant in determining a reasonable LPD. In some cases, the spacing of the luminaries and other features change for each lighting zone.
4. *Calculations*. Perform lighting calculations for each of the models using the selected lighting equipment. The purpose of the calculations are to verify that the lighting design criteria is being satisfied. The lighting equipment and lighting layout are modified such that the design criteria are satisfied. The lighting power used to meet the criteria is the basis of the proposed standards.

For billboards and signs, a different approach is taken, based on manufacturers' recommendations. The highest reported recommendation is the basis of the LZ4 standard. The recommendation at the 75th percentile is used for LZ3. The standard for LZ2 is set to be half the LZ3 standard. In LZ1, the lighting power is limited to 20 W per sign face or is not recommended.

Acknowledgments

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Lighting Zones

Description

The California Energy Commission (CEC) has identified the need for four different lighting zones or geographical areas, titled LZ1, LZ2, LZ3 and LZ4, which are based on the environmental zones recommended by both the Commission Internationale de l'Eclairage[3] (CIE) and the Illuminating Engineering Society of North America (IESNA).[4] Each zone may have different requirements for outdoor lighting. Lighting zones serve a similar function as the climate zones already defined in the Title 24 energy standards that determine requirements for insulation and fenestration performance.

The amount of outdoor lighting required at night for any given visual task is partly a function of its surrounding ambient lighting conditions. The human eye is highly adaptable to different levels of light, but requires time, from seconds to minutes, to adjust to changes in illumination levels. In intrinsically dark environments, visual performance can be maintained at comparably lower levels of illumination, while in areas of high ambient illumination, higher levels of illumination are required for the same task. By maintaining zones of lower ambient illumination where appropriate, visual needs and public safety can be preserved while also reducing the state's energy needs.

The lighting zone approach allows each outdoor lighting standard to be based on the quantity and quality of light that is appropriate to the use and settlement patterns of a local area. Overly high limits do not have to be set for all conditions, and likewise, overly restrictive regulations do not have to apply to areas in brightly lit situations. This enables energy savings to be optimized for each lighting zone.

Other benefits include reduced light trespass and light pollution by zone, specific protection of wildlife from excessive light at night in designated natural areas, and public review and participation in the process of setting the environmental area zoning definitions. The environmental zone approach allows for variation in standards by local preferences, within the maximum and minimum conditions allowed.

Defining Lighting Zones

LZ1 would be defined to include state and national parks, wilderness areas, and wildlife preserves. LZ2 would be defined as those areas that are designated as rural by the U.S. Census Bureau and do not qualify as LZ1 according to the previous definition. LZ3 would be defined as those areas designated as urban by the U.S. Census Bureau. Lighting zones would be designated through a process of statewide defaults based on defined geographical areas, and local government amendments that adjust the zones for local conditions. The CEC would maintain a web-based map of lighting zones, based on information from state agencies on LZ1 areas, and the U.S. Census Bureau for LZ2 and LZ3. Table 2 contains recommended definitions of the four California lighting zones.

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[3] Commission Internationale de l'eclairage. "Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations." Report of committee TC5.12 – Obtrusive Light. Vienna, Austria: CIE.

[4] Illuminating Engineering Society of North America. RP-33-99 "Lighting for Exterior Environments." New York, NY: IESNA. 1999.

Table 2 – Lighting Zone Definitions

Zone	Ambient Illumination	State Default Location	Rules for Amendments by Local Jurisdictions: Moving Up to the Next Zone	Rules for Amendments by Local Jurisdictions: Moving Down to the Previous Zone
LZ1	Dark	State and national parks, recreation areas, and wildlife preserves.	A state or national park or recreation area, or portions thereof, can be designated as LZ2 or LZ3 if they are contained within or adjacent to such a zone.	Not applicable.
LZ2	Low	Rural areas, as defined by the most recent U.S. Census.	Special districts within a default LZ2 zone may be designated as LZ3 by a local jurisdiction. Examples include special commercial or industrial districts located within a rural area. Special LZ3 areas must be at least one mile away from any LZ1 area, and may not exceed a dimension of more than 4 miles in direction.	Special districts within a default LZ2 zone maybe designated as LZ1 by the local jurisdiction for lower illumination standards. No size or adjacency limits.
LZ3	Medium	Urban areas, as defined by the most recent U.S. Census.	Special districts may be designated by local jurisdiction for high intensity nighttime use, such as adult entertainment districts. Individual LZ4 areas must be at least 2 miles from any LZ2 area and 4 miles from any LZ1 area. LZ4 areas shall not exceed a dimension of more than 2 miles in any direction. No city shall designate more than 10% of its total dry land area as LZ4.	Special districts within a default LZ3 zone may be designated as LZ2 by the local jurisdiction. No size or adjacency limits.
LZ4	High	None.	Not applicable.	Not applicable.

Urban areas are defined by the U.S. Census Bureau according to a series of set rules. First, an urban core is identified at 1,000 persons per square mile (about 2 to 4 dwelling units per acre). Then contiguous areas that have a density of at least 500 persons per square mile (0.5 to 1.0 dwelling units per acre) are added at the grain of single census blocks or block groups. Small unoccupied areas are allowed under a set of rules based on size and density, until a continuous urban area is defined. No rural islands are defined within an urban area.

Urban and rural areas are officially defined by the U.S. Census Bureau every decade. These geographic definitions figure into a number of federal rules and regulations. The most extensive use of census urban/rural boundaries is made by the Federal Highway Administration (FHWA) and other transportation agencies. The legislation governing the FHWA (Title 23 of the U.S. Code) uses census geography boundaries in defining urban areas, small urban areas, and rural areas with only slight modifications from the census definitions (Section 101, Part 29, 36,37). Urban/rural areas are also commonly used for federal funding allocations to states, for regulation of utilities and public services, and for federal statistical reporting. Reporting agencies using the urban/rural definitions include Highway Performance Monitoring System (HPMS), Fiscal Management Information System (FMIS), Structure Inventory and Appraisal System (bridge file), Fatality Analysis Reporting System (FARS under the National Highway Traffic Safety Administration), as well as other traffic monitoring activities (volume trends, vehicle class, WIM, etc.), and financial (HPM-10) reports.

Urban/rural designations are readily available from the U.S. Census Bureau or other public sources that provide census information by map or census block. Web services allow users to search for specific location via address.

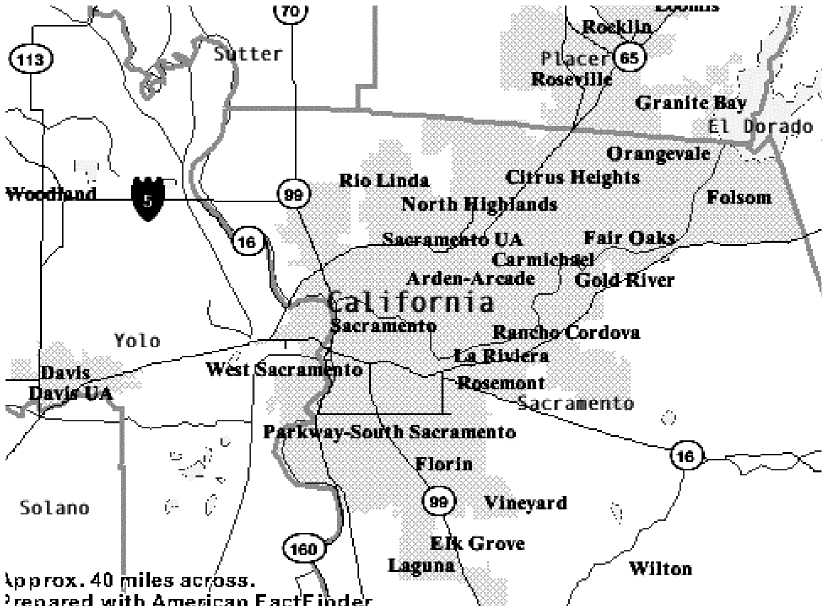

Figure 2 – Example of Urban/Rural Designation from U.S. Census 1990
Grey represents urban areas (default LZ3). White are rural areas (default LZ2).

Local jurisdictions would be required to officially adopt modifications and notify the CEC of any changes to the lighting zone areas, or to designate an LZ4 area. The CEC would then publish the new areas two times per year by updating the web site. With GIS web features, an applicant could type in any address and be told the current lighting zone designation.

Local jurisdictions would be provided with a lighting zone designation form to submit to the CEC. It would take effect in 60 to 90 days, allowing time for review and comment by the CEC. Jurisdictions would be required to follow their normal public process, with an opportunity for formal public comment and review, before adopting a change to the default lighting zone designation for any area or property. They would also be required to notify the CEC of the change in designation, with specific GIS coordinates or census block areas effected, so that the change can be added to the published (web-based) statewide mapping of lighting zone areas. It may be most convenient to require that changes be made according to census block areas, so that they can easily be integrated with the current U.S. Census map of rural and urban areas.

The local jurisdiction would have authority to amend the default lighting zones.

Proposed Standards Language

The following language is recommended.

Lighting Zone	A geographic area designated by the CEC which determines certain requirements for outdoor lighting, including lighting power densities and specific control, equipment, or performance requirements.
Curfew	A time period during the night during which some outdoor lights are required to be turned off or dimmed.
Daytime Hours	The time period from 30 minutes after sunrise to 30 minutes before sunset.

A) **Daytime Controls**: Certain outdoor lighting equipment will be required to have photocontrols that will insure that the equipment is turned off during the daytime hours.

B) **Curfew Controls**: Outdoor lighting equipment will be required to have controls that will allow lighting equipment to be turned off or reduced during curfew periods. Curfews can be set locally. Example curfews for each lighting zone are shown in Table 3.

Table 3 – Example Curfew Times

	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Lighting Curfews	8 PM until sunrise	10 PM until sunrise	12 PM until one hour before sunrise	2 AM until one hour before sunrise

C) **Lighting Power Allowances**: Lighting power allowances are designated by California Lighting Zone (LZ). LZ1 has the lowest lighting power allowances and LZ4 has the highest. The specific allowances for each lighting zone are discussed under each measure.

D) **Amending the Lighting Zone Designation**: A local jurisdiction can designate specific lighting curfew times for their area, or change the lighting zone designation of an area by following their normal public process that allows for formal public notification, review, and comment about the proposed change. A lighting zone may be increased or decreased by one zone, according to local preference, according to the rules set forth in Table 2.

Bibliography and Other Research

Commission Internationale de l'eclairage. "Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations." Report of committee TC5.12 – Obtrusive Light. Vienna, Austria: CIE.

EPRI. TR-114914, "Light Trespass Research." Palo Alto, CA, 2000.

EPRI Lighting Research Office, IESNA/LRO proceedings on Outdoor Lighting; February 25-27, 2002 (to be published).

Federal Highway Administration (FHWA). Title 23 of the United States Code, definitions of census geography.

Illuminating Engineering Society of North America. RP-33-99 "Lighting for Exterior Environments." New York, NY: IESNA. 1999.

Illuminating Engineering Society of North America. RP-8-00 "American National Standard Practice for Roadway Lighting." New York, NY: IESNA. 2000.

Illuminating Engineering Society of North America, TM-11-00 "Light Trespass Research, Results and Recommendations." New York, NY: IESNA. 2000.

Moore, Chadwick A., "Visual Estimations of dark Sky Brightness." http://www.georgewright.org/184moore.pdf. The George Wright Society, Inc., Hancock, MI, 2001.

New Buildings Institute. Advanced Lighting Guidelines 2001. White Salmon, WA: NBI. 2001.

Public Resources Code. Division 20, California Coastal Act. January 2002.

U.S. Census. 2000.

Measure 1 – Unconditioned Buildings

Description

This measure expands the scope of the Title 24 building energy efficiency standards to include requirements for unconditioned spaces, which are currently not regulated. The requirements include prescriptive lighting power density requirements and mandatory lighting control requirements.

Adding unconditioned buildings to the standards utilizes measures that are already identified for the 2005 standards revision or already included in Title 24 for conditioned buildings. While the parking garage model and standard are new, the others are not. The lighting technologies used as the basis of all of these measures are the same.

Design Criteria

The approach is to demonstrate that the Illuminating Engineering Society of North America (IESNA)-recommended illuminance lighting criteria in unconditioned buildings can be satisfied with cost effective, efficient lighting equipment. The lighting power density (LPD) identified in verification models serves as the basis of the 2005 Title 24 standard.

The types of buildings and building areas that may be constructed without permanent heating or cooling are identified and may be built without needing to comply with the current Title 24 standard. The LPD models from the proposed 2005 Title 24 energy standard for conditioned and semi-conditioned buildings are compared to typical types of unconditioned buildings. The existing models of conditioned buildings work well for unconditioned buildings, since the tasks are the same. No existing California Energy Commission (CEC) model exists for parking garages, so a new one is developed.

As with all Title 24 energy regulations, the existing models for conditioned areas are cost effective. Since the rational is the same, this cost effectiveness also results when the models are applied to unconditioned spaces.

IESNA Classifications

IESNA models used to develop standard 90.1 for parking garages include area space type models for pedestrian and for attendant-only parking.

IESNA Area Space Type Models

These models define typical room parameters for each space type, based on room cavity ratio and luminaire assumptions. Fluorescent lamps in lensed luminaires are the assumed light source for all garage applications. The planned lighting levels are based on IESNA recommendations from the IESNA Lighting Handbook, Ninth Edition. For the pedestrian garage area, 90% of the area is for parking with a recommended maintained average illuminance of 5 footcandles, while 10% is general lighting for ingress and egress with a maintained average illuminance of 50 footcandles. The recommended LPD is 0.23 W/ft^2. In the attendant parking area model, all area is for parking, and the recommended LPD is 0.12 W/ft^2.

IESNA Whole Building Models

Each IESNA whole building model is composed of smaller areas represented in the IESNA area models but expressed as a percentage of the whole building. The appropriate area percentage is multiplied by the LPD for each area, and the sum of all resulting LPDs is the whole building LPD. For whole building garages, the models include three examples, and each uses the pedestrian garage area model for over 85% of the building area. Other small areas in the whole garage models are office, stairs, elevator, computer task, and utility/storage. The largest whole garage model also includes small areas for post office, vending, hallway, and electric/mechanical. IESNA arrives at a recommended LPD of 0.35 W/ft^2 by averaging all three whole building model recommendations.

Comparing the Models

Parking structures are represented in IESNA models but not in CEC models. Since the methods of IESNA calculations are different from those used in CEC models, a new model using CEC methods is developed for a parking garage. A typical conservative garage area is modeled, using the following criteria:

- Dimensions and surfaces are a 150 ft long by 50 ft wide by 9 ft. tall garage section, with diffuse reflectances of 0.30 ceiling, 0.30 walls, 0.20 floor to represent concrete.
- Fluorescent T-8 striplights are the selected luminaire, using second-generation T-8 lamps and electronic ballasts. Title 24 research for indoor spaces shows this technology to be cost effective.
- Similar to the IESNA models, a 50-footcandle target for the task area, representing 10% of the space, is selected for the entrance and exit areas. A 5-footcandle target for the remaining 90% represents the actual parking area.

Lighting Equipment

Lighting equipment used for the models is readily available from multiple sources. These technologies are cost effective, as demonstrated for conditioned and semi-conditioned building applications.

The parking garage model assumes T-8 second-generation "super" fluorescent lamp as the basis of the recommended LPD. Other lighting technologies that might also provide similar efficiencies include:

1. T-5 fluorescent lamp, which provides energy savings similar to the second generationT-8 lamp. This is an alternate lamp.
2. Metal halide (MH) "pulse-start" lamp.

These lighting technologies are part of the CEC 2005 Energy Efficiency Building Standards Update Lighting Power Allowances revision. See http://www.energy.ca.gov/2005_standards/documents/2002-04-23_workshop/2002-04-23_WORKSHOP_REPORT.PDF for a discussion and cost analysis.

High-pressure sodium (HPS) lamps may also provide similar or better lighting power, if that source meets other design requirements.

Since all buildings create indoor spaces and use indoor luminaires, outdoor luminaire cutoff classifications do not apply.

Temperature Concerns with Fluorescent Lamps

One potential concern is the temperature sensitivity demonstrated by some fluorescent light sources. The light output from fluorescent lamps can change with temperature variation. However, fluorescent lamps have been widely used in unconditioned buildings throughout California, indicating that temperature sensitivity is not a problem.

One key reason why the temperature sensitivity of fluorescent lamps does not prevent their use in unconditioned spaces is that lamp temperature will rise above ambient conditions once the system is operating. Selecting an appropriate luminaire can adjust lamp-operating temperature to alleviate these effects. For those applications where ambient temperature could be extremely detrimental to the light produced by fluorescent lamps, MH lamps also offer excellent lighting efficiency with little temperature sensitivity.

An additional concern about using fluorescent lamps in unconditioned buildings is that some lamp-ballast combinations will not allow lamp starting at reduced temperatures. This is especially prominent with older 34-W, energy saving T-12 lamps operated on magnetic ballasts, which sometimes show poor starting at temperatures as high as 60°F. However, many instant start electronic ballasts will start lamps in ambient temperatures as low as 0°F, which is sufficient for wide fluorescent lamp application. If starting a lamp at an even lower temperature becomes an issue for a rare application, careful lighting design using pulse start MH lamps or high output T-8 fluorescent lamps will meet the requirements.

Lighting Models

CEC Models

The CEC has modeled 39 area categories and 14 complete building models for the 2005 Title 24 revision. Unconditioned buildings typically fall into categories shown in Table 4, which are selected from the area and building categories. The CEC considered IESNA design guidelines when it established these existing area and whole building LPDs for building energy standards.

Table 4 – Typical Area Categories for Unconditioned Buildings

Area Categories	Allowed Lighting Power (W/ft^2)
Auto Repair	1.1
Commercial and Industrial Storage	0.6
Corridors, Restrooms, Stairs, and Support Areas	0.6
Electrical, Mechanical Rooms	0.6
General Commercial and Industrial Work:	
High Bay	1.1
Low Bay	1.0
Precision	1.3
Kitchen, Food Preparation	1.6
Laundry	0.9
Locker/Dressing Room	0.8
Transportation Facilities (baggage-ticket-waiting)	1.2

Table 5 – Typical Complete Building Categories for Unconditioned Buildings

Complete Building Categories	Allowed Lighting Power (W/ft^2)
General Commercial and Industrial Work Buildings:	
High Bay	1.1
Low Bay	1.0
Industrial and Commercial Storage Buildings	0.7

CEC Model Details

The CEC models consist of spreadsheets showing calculations for each category type. As shown in Table 6, the models include a number of details:

- Room details are type, dimensions, and finishes (e.g., room surface reflectances).
- Light Level = the design illuminances for task and ambient plans in this space.
- Light Loss Factor represents the sum of the light depreciating factors (e.g., maintenance factor), less the lamp lumen depreciation, which is included in the mean lamp lumen rating. The IESNA Lighting Handbook recommends light levels and light loss factors used in these models.
- Under the Lighting Systems heading, details include lamp (e.g., rated at mean lumens, output at 40% of rated lamp life) and luminaire information, percent of total light provided by each lighting system, and the coefficient of utilization (CU) for each luminaire specified.
- Under the Calculations heading:
  - The lumens required from each lighting system and the lamp power needed to provide those lumens for each system are listed.
  - Net Lumens = maintained light necessary to provide specified illumination, shown as both a total of all systems and for individual systems.
  - Gross Lumens = light before applying the CU.

  - Lamp Lumens = Gross Lumens before applying the light loss factor.
  - Minimum Theoretical Watts = the sum of total lamp power needed from each lighting system.
  - Minimum Theoretical Power Density = the quotient of the Minimum Theoretical Watts divided by the space area.
- Recommended Value for Standard (e.g., allowable lighting power, W/ft^2) is the Minimum Theoretical Power Density rounded up to provide some design flexibility.

The CEC model also computes the necessary luminous flux for the illuminance targets, along with the required lighting power and resulting LPD.

Calculations

Table 6 – Parking Garage Model

Space Type	Parking Garage		
Length	150		
Width	50		
Height	9		
Finishes	Code 6: 03/30/20		
Light Level	**Footcandles**	**% of space**	
Task	50	10	
Ambient	5	90	
Other			
Light Loss Factor	0.70		
Lighting Systems	**#1**	**#2**	**#3**
Lamp	T8/T5	T8/T5	
Luminaire	Direct	Direct	
Source Code	6	6	
RCR	1.20		
Percent of Total	53	47	
CU of Fixture	0.63	0.63	0.001
Note/Source	Lithonia SL	Lithonia SL	
Calculations			
Average FC	10.85		
Total Net Lumens	81375		
Net Lumens #1	43128.75	**Gross Lumens #1**	68458.3
Net Lumens #2	38246.25	**Gross Lumens #2**	60708.3
Net Lumens #3	0	**Gross Lumens #3**	0
Lamp Lumens #1	97797.6	**Lamp Watts #1**	1086.6
Lamp Lumens #2	86726.2	**Lamp Watts #2**	963.6
Lamp Lumens #3	0	**Lamp Watts #3**	0
Minimum Theoretical Watts			2050
Minimum Theoretical Power Density			0.2734
Recommended Value for Standard			0.30

Data Used in Calculations

Source Codes	Lamp Types	MLPW
1	Incandescent	10
2	Halogen	15
3	Halogen IR	20
4	Compact Fluorescent	55
5	Biax/T5HO	75
6	T8/T5	90
7	Ceramic MH	50
8	Pulse start MH	75
9	Other	70

Finish Codes	Reflectances	Fixture Types
1	80/70/20	Direct
2	80/50/20	Semi-direct
3	70/50/20	Direct-indirect
4	70/30/20	Semi-indirect
5	50/50/20	Indirect
6	30/30/20	Diffuse
		Directional

Recommendations

This proposal recommends changing the references in Section §100 and others, so they do not exclude unconditioned buildings from complying with the energy standard. Applicable sections that apply to unconditioned buildings include §130-132 for mandatory lighting controls and equipment, and §146 for prescriptive lighting requirements.

A new area category, Parking Garage at 0.30 W/ft^2, would be added to Table 1-N, Section §146.

A new fifth paragraph number would be included in Section §150 (k) Lighting, stating that if a low-rise residential building includes a parking garage (see definitions) for eight or more motor vehicles, then it must comply with lighting control mandatory requirements in Section §130.

Definitions

Parking Garage	A building or structure intended for parking eight or more vehicles. A parking garage consists of at least a roof over the parking area, often with walls on one or more sides. It may have fences or rails in place of one or more walls. The structure has entrance(s) and exit(s), and includes areas for vehicle maneuvering to reach the parking spaces. If the roof of a parking structure is also used for parking, the section without an overhead roof is considered a parking lot instead of a parking garage.

Bibliography and Other Research

American Society of Heating, Refrigerating, and Air-Conditioning Engineers. Lighting power density models for ASHRAE/IESNA 90.1-1999 Standard. Found on web site at http://206.55.31.90/cgi-bin/lpd/lpdhome.pl.

California Energy Commission. Spreadsheets for the 2005 nonresidential lighting standards. http://www.energy.ca.gov/2005_standards/documents/2002-04-23_workshop/2002-04-23_WORKSHOP_REPORT.PDF.

Illuminating Engineering Society of North America. IESNA Lighting Handbook, Ninth Edition. New York, NY: IESNA. 2000.

New Buildings Institute, Advanced Lighting Guidelines 2001. White Salmon, WA: NBI. 2001.

Measure 2 – Parking Lot Lighting

Description

This measure establishes maximum lighting power allowances and control requirements for outdoor parking lots. The requirements apply to any parking area that is lighted, including landscaped parking lot islands. It does not include parking areas that are not lighted. The requirements vary with lighting zones. This provides a way to compensate for sites with significantly different ambient light conditions. The recommended lighting power ranges from 0.04 in LZ1 to 0.20 in LZ4.

Additional control requirements are also recommended. In addition to the photocell or timeclock already required by §131(f), a timeclock must be provided to turn off or reduce lighting for curfew hours. The lighting control must also be capable of reducing lighting to 50% of full power during one stage of curfew.

The 60 lumens per watt efficacy requirement of §130(c) applies to all parking lot lighting with lamps larger than 100 W. In addition to this, a new provision will require cutoff luminaires be used for parking lot lighting applications.

Design Criteria

The Illuminating Engineering Society of North America (IESNA) recommendations several methods for lighting parking lots. Methods are listed in the “Lighting for Exterior Environments” (RP-33-99), Lighting Handbook 9th Edition, “Roadway Lighting” (RP-8-00), and “Lighting for Parking Facilities” (RP-20-98). Since these recommendations are not entirely consistent with each other, RP-20-98 is being used as the basis of the design criteria for parking lots. This is the most comprehensive of the three and it was developed by the IESNA committee responsible for parking lot lighting recommendations. The other IESNA guides and handbooks reference RP-20-98 as the primary source.

RP-20-98 provides design criteria for two categories of parking lots. The first is for Basic parking lots, which represents the typical parking lot condition. The second addresses Enhanced Security situations, which is for situations where personal security or vandalism is a likely and/or severe problem. For each of these categories, the criteria is stated in terms of:

- *Minimum horizontal illuminance (footcandles).* The minimum horizontal illuminance level is the lowest maintained lighting level that is recommended. Typically, this minimum point occurs in the middle of a grid of four poles.
- *Minimum vertical illuminance (footcandles).* The minimum vertical illuminance is the lowest maintained lighting level at 5 ft above the pavement in the four cardinal directions located at the minimum horizontal illuminance location.
- *Uniformity (ratio of maximum to minimum horizontal illuminance).* The horizontal illuminance maximum to minimum uniformity is the worst-case uniformity that is recommended between a standard grid of poles. Uniformity ratios lower than the recommended value are desired since they represent more even lighting.

Lighting design criteria is selected for the four lighting zones: LZ1, LZ2, LZ3 and LZ4. For LZ2, the recommended design criteria for Basic parking lots are used. For LZ3, the design criteria for Enhanced Security parking lots are used. The LZ4 criteria have increased lighting levels above the Enhanced Security values.

Table 7 – Design Criteria for Parking Lots

Lighting Zone	Minimum Horizontal Illuminance	Minimum Vertical Illuminance (5 ft above pavement)	Horizontal Illuminance (max/min ratio)
1	0.1	n. a.	20:1
2	0.2	0.1	20:1
3	0.5	0.25	15:1
4	1.0	0.50	10:1

Note: The LZ4 values are based on Table 1, Footnote 2 (higher horizontal illuminance desired by retailers) and Footnote 7 (higher vertical illuminance per the IESNA Security Lighting Committee). The LZ1 criteria are based on Table 1, Footnote 1 (periods of non-use).

Lighting Equipment

Lamps

The lamps used for the model are all metal halide lamps. These lamps have slightly lower luminous efficacy than high pressure sodium lamps, and represent the more conservative design approach for lighting power density (LPD). White light sources, like the metal halide lamp, have a significant benefit in low light level visibility, especially in peripheral detection of movement that researchers are only now beginning to understand. This benefit has not been considered for the model, which results in another conservative layer to the results.

The metal halide lamps used are standard output, universal burn (i.e., non-position-oriented) lamps, operated with a constant-wattage autotransformer (CWA) ballast, a typical ballast for this type of luminaire. All lamps are operated in the horizontal position. Provided below are the output and energy characteristics for the metal halide lamps/ballast combination used for the model.

Table 8 – Lamp Performance for Parking Lots

Type (metal halide)	Input Watts	Mean Lumens	Efficacy (mLm/W)
70W	90	4950	55
150W	185	9920	54
250W	310	13500	44

Luminaires

All the lighting calculations were performed using an IESNA Type V distribution "shoe box" luminaire with anodized hydroformed aluminum reflector, flat lens, and full cut-off optics. Type V optics are commonly used for parking lot applications. The distribution of the light from a Type V luminaire is a symmetric circle or square on the ground, centered below the luminaire. This results in an efficient coverage of light on the ground when using a grid of poles as is typically used in a parking lot. Typical pole heights of 20 ft, 25 ft, 30 ft and 35 ft will be used as appropriate for the lighting zone.

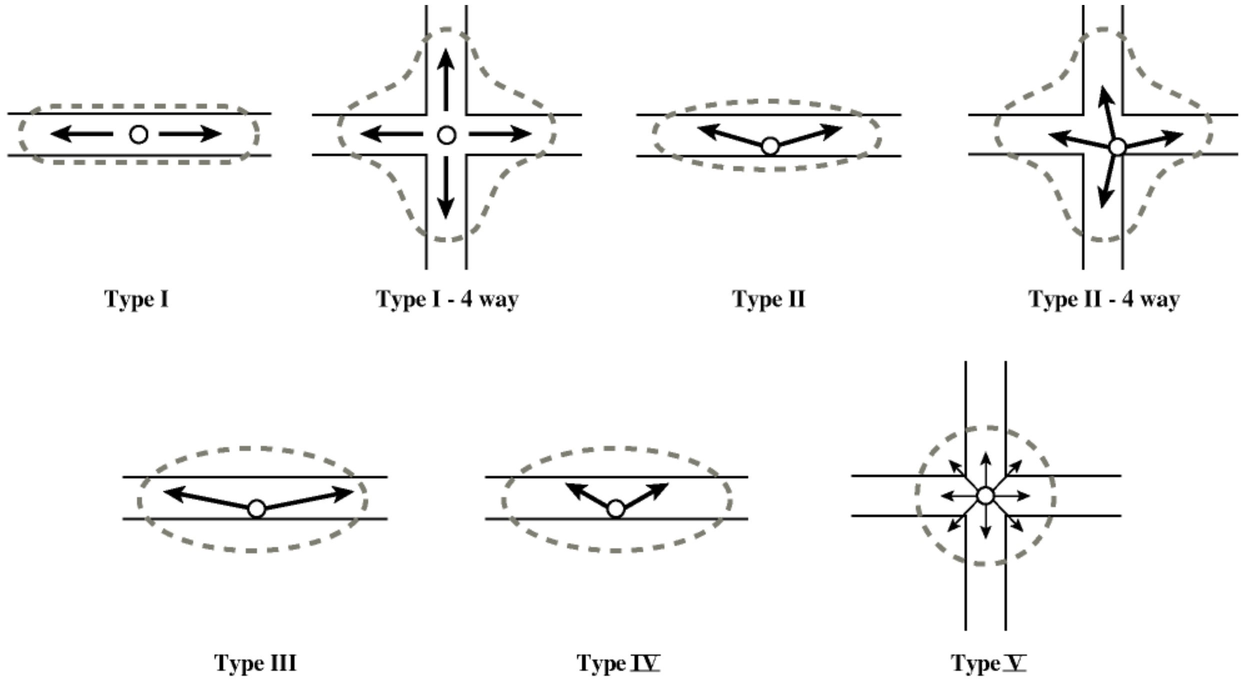

Figure 3 – Light Distribution Patterns for Outdoor Luminaires

Hydroformed optics are commonly used in parking lot applications, and are moderate in performance and overall quality of light control. The highest quality optics typically are “segmented,” followed by “hydroformed,” and finally ”refractor” optics, which are generally the worst performers.

Some parking lot designs utilize a vertically-oriented lamp in Type V optics. While this will produce better uniformity on the ground, the glare produced by this luminaire type is generally unacceptable. The use of a horizontally-oriented lamp represents a more conservative design approach.

Equipment selection can vary greatly for parking lot lighting. In establishing lighting designs that produce the least amount of glare, only IESNA full-cutoff [TM15]luminaries are used in the models [llh16]to establish maximum lighting power densities. While the standard does not require full-cutoff luminaires, their use in the models verifies that compliance with the proposed standard can be achieved with the full-cutoff luminaire.

Lighting Models

The parking lot lighting model is based on typical parking lot dimensions found in commercial development. Typical parking lot design follows general guidelines for width of drive lanes, length and width of parking stalls, and other variables.

The typical parking facility has a drive lane that is 30 ft wide to accommodate two-way traffic. The parking spaces are typically 15 ft long and 10 ft wide. The typical row-to-row spacing for a parking lot will be 60 ft. If there is a grass divider or sidewalk in between the rows of parking spaces, the row spacing will increase.

For these calculations, a 3x3 grid of nine poles is established, and the calculation is performed towards the middle of the grid. The calculation grid begins at the center pole and covers the area from there to a point one-half of the way to the next pole to the east in the grid, and also from there to a point one-half of the way to the next pole to the north in the grid. This represents one-fourth of the area defined by four poles in the grid. Because of the symmetry and repetition in the lighting system, only a portion of the whole layout needs to be calculated to represent the entire system. See Figure 4.

The lighting power for the parking lot is calculated based on *the area that each light pole is assigned to.* The area assigned to a particular pole is represented by a rectangle that is centered about the pole, and covers an area one-half of the distance from the pole to the next pole in every direction. See Figure 4.

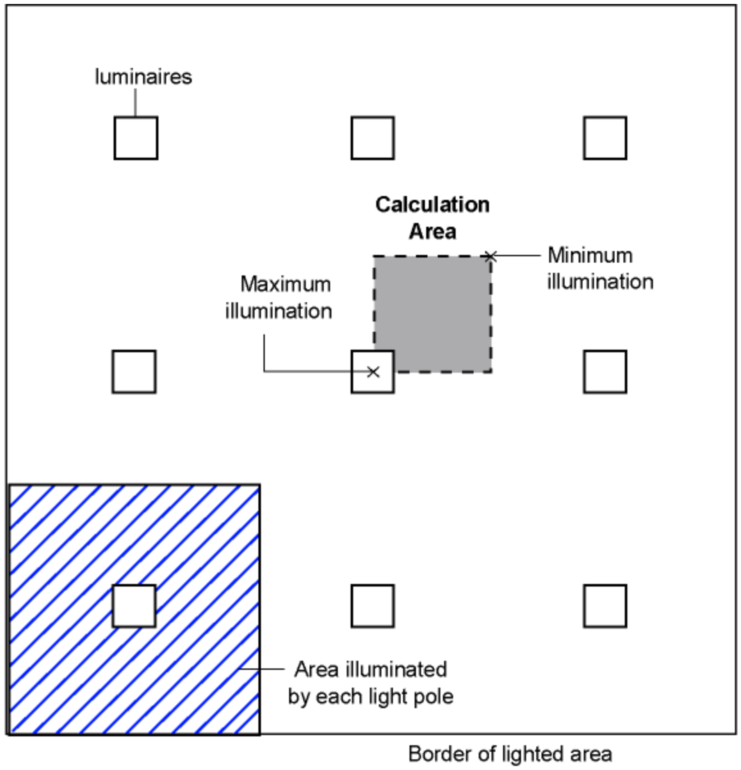

Figure 4 – Calculation Grid for Parking Lots

Pole heights and luminaire wattages typically increase as the size and light level requirements of the parking lot increases. The typical pole height and lamp wattages used are based on commonly used combinations and are then adjusted to meet the lighting criteria for the particular parking lot classification.

At some point, large parking lots will be able to skip a row of parking, and only have lighting equipment in every other row. This is difficult to model accurately, because it is heavily dependant on the height of the pole, and the specific performance of the optics in the luminaire. These lots will typically use a high-quality optical system in the luminaire. These parking lots will typically use less energy than a comparable lot with lower poles, so the lower pole mounting heights selected for the higher lighting zones is a conservative calculation.

Calculations

All parking lot lighting calculations are performed with the AGI-32 v1.50 software, by Lighting Analysts, Inc. AGI32 is a lighting calculation program that will perform point-by-point calculations of exterior lighting designs based on the specification of the geometry, the luminaire information, and relevant lumen maintenance information for the model. Calculations can be performed for horizontal and vertical illuminance and luminance within a grid, and computation of uniformity ratios are provided for the calculations.

The luminaire dirt depreciation factor (LDD) used for the model is assumed to be 0.7, which represents a “dirty” air environment typically found only near manufacturing facilities and in very dusty environments. For most applications this will represent a conservative design approach.

The initial design for each parking lot classification is selected based on “common” pole heights, lamp wattages, and pole spacing used for parking lot lighting considering the likely surrounding neighborhood conditions and size of the parking lot. This initial design is then modified based on the results of the calculations until the criteria are met.

The initial lighting criteria for parking lot lighting design are *average illuminance* and *minimum vertical illuminance*. These are first met by adjusting the lamp wattage and pole spacing to meet the guidelines. The *horizontal illuminance ratio* criterion is then checked to verify that it is satisfactory. If the uniformity criterion is unacceptable, the spacing is decreased to meet the level established.

The results indicate that it is possible to meet the illuminance criteria and easily meet the uniformity criteria. The limiting factor for all the lighting designs appears to be the minimum vertical illuminance. The reason for this is that the full cutoff light distribution of the luminaire minimizes the light that propagates out at small angle below horizontal. Light that propagates from horizontal to about 10° below horizontal is the largest source of glare, light trespass, and lighting complaints. It also is very efficient at increasing the vertical illuminance for a lighting design.

As the lighting criteria decrease (i.e., as the lighting zone decreases), it becomes increasingly difficult to meet the vertical illuminance criteria. The reason for this is that the vertical illuminance is controlled heavily by the height of the luminaire, and as the pole height decreases, the size of the area that the luminaire illuminates is diminished. At a point, the pole height cannot support the 60 ft minimum spacing that is required for two parking spaces and a drive lane.

Table 9 – Lighting Calculations – Parking Lots

		LZ1	LZ2	LZ3	LZ4
Lighting Power Density	Recommended Criteria	0.040	0.060	0.080	0.200
	Calculated	0.037	0.052	0.079	0.194
Minimum Horizontal	Criteria	0.1	0.2	0.5	1.0
	Calculated	0.1	0.2	0.6	1.2
Minimum Vertical	Criteria	---	0.1	0.25	0.5
	Calculated	---	0.1	0.4	0.5
Uniformity	Criteria	20:1	20:1	15:1	10:1
	Calculated	15:1	10.5:1	4:1	2.25:1
Luminaire Type		Type V	Type V	Type V	Type V
Lamp (metal halide)		70 W	150 W	15 0 W	250 W
Pole Height		25 ft	25 ft	30 ft	35 ft
Spacing		60 ft x90 ft	100 ft x80 ft	75 ft x70 ft	60 ft x60 ft

Recommendations

Definitions

Parking Area	An outdoor, paved, or unpaved nonresidential area, designed for or functioning as parking for motor vehicles.
Lighted Parking Area	The lighted parking area is defined as the physical parking area, including planting islands, that is lighted. If only a portion of the area is lighted, then the lighted portion includes all lighted areas plus the area of 2.5 times the mounting height past the last pole, as illustrated in a square pattern. The square pattern is established by producing a square around the pole that is five times the luminaire mounting height. Locate the pole in the middle of the pattern to determine the 2.5 times mounting height distance.
Lighting Controls	Photosensors, programmable time clocks, or yearly astronomical controls will be required to turn off all pre-curfew lighting during daylight hours. Parking lot lighting will be required to turn off or be reduced during curfew, according to environmental zones. Motion sensors may be required to turn off or reduce lighting power during curfew hours, according to environmental zones.

Allowed Power

The installed lighting power shall not exceed the values provided in Table 10.

Table 10 – Allowed Lighting Power – Parking Lots

	LZ1	LZ2	LZ3	LZ4
Lighting Power Density	0.040	0.060	0.080	0.200

Controls

Controls must be provided that are capable of reducing lighting power to at least 50% of full output in LZ2, LZ3, and LZ4. In LZ1, the controls must be able to reduce lighting power to at least 10% of full output. See Table 11. The best means of meeting this requirement is to install high-low ballasts. An alternate means would be to circuit the luminaires so that all are turned off during curfew.

Table 11 – Control Requirements for Parking Lots

	LZ1	LZ2	LZ3	LZ4
Parking Area Pre-curfew	100%	100%	100%	100%
Parking Area Post-curfew	10%	50%	50%	50%

Bibliography and Other Research

Illuminating Engineering Society of North America. IESNA RP-20-98, “Lighting for Parking Facilities.” New York: IESNA.

Measure 3 – Building Grounds

Description

This measure establishes maximum lighting power levels permitted for outdoor building grounds lighting, and includes hardscape areas such as walkways, ramps, stairs, plazas, and other outdoor pedestrian areas. It does not include hardscape areas that are not lighted or areas within a 5 ft zone from building edge. The measure will employ Illuminating Engineering Society of North America (IESNA) lighting zones as a method to compensate among sites with significantly different ambient light conditions.

Luminaires larger than 100 W must be of the cutoff type as defined by IESNA.

Sports lighting is not included in this measure.

Design Criteria

The current IESNA recommendations list several methods for lighting building grounds. Methods are listed in the “Lighting for Exterior Environments” (RP-33-99); Lighting Handbook, Ninth Edition; “Roadway Lighting” (RP-8-00); and “Lighting for Parking Facilities” (RP-20-98). The recommended practice selected for the lighting models is IESNA publication “Roadway Lighting” (RP-8-00), since it is the most comprehensive recommended practice for walkways and originated from the IESNA committee responsible for walkway lighting recommendations. Other IESNA recommendations reference RP-8-00 as their primary source.

For walkway lighting, RP-8-00 criteria include illuminance criteria for different pedestrian conflict zones and use types. For the lighting models, average horizontal illuminance levels in footcandles, minimum vertical illuminance in footcandles, and horizontal illuminance average to minimum uniformity are stated. The average horizontal illuminance level is the lowest average maintained lighting level that is permitted between a standard grid of poles. The horizontal illuminance average to minimum uniformity is the worst-case uniformity that is recommended between a standard grid of poles. Uniformity ratios lower than this are desired since it represents more even lighting. The minimum vertical illuminance is the lowest maintained lighting level at 4.9 ft above the pavement in the four cardinal directions, located at the minimum horizontal illuminance location. For a typical standard walkway, this minimum point occurs at the mid-point of walkway between two luminaires or poles.

For walkway and bikeway lighting, RP-8-00 lists criteria for low and medium pedestrian conflict zones for different use categories. Low pedestrian conflict in rural/semi-rural area is used for Lighting Zone (LZ) 1. Low pedestrian conflict in low-density housing is utilized for LZ2. LZ3 uses low pedestrian conflict in medium-density housing, with high pedestrian conflict being used for LZ4. Table 12 shows the design criteria used for this research.

Table 12 – Design Criteria for Building Grounds

Lighting Zone	Average Horizontal Illuminance	Minimum Vertical Illuminance (4.9 ft above pavement)	Horizontal Illuminance avg/min ratio
1	0.20	0.06	10:1
2	0.30	0.08	6:1
3	0.40	0.10	4:1
4	0.50	0.20	4:1

Lighting Equipment

The lamp used for the lighting models is a metal halide (MH) lamp. This lamp has a slightly lower luminous efficacy than high-pressure sodium (HPS) lamps, and represents the more conservative design approach for lighting power density (LPD). White light sources, like the MH lamp, have a significant benefit in low light level visibility that researchers are only now beginning to understand. This benefit has not been considered for the model, which results in another conservative layer to the results.

The MH lamp used is a standard-output, universal burn (non-position-oriented) lamp, operated with a constant-wattage autotransformer (CWA) ballast, a typical ballast for this type of luminaire. All lamps are operated in the horizontal position. Provided below is the output and energy characteristics for the MH lamp used for the model.

Table 13 – Lamp Performance Data – Building Grounds

Type	Input Watts	Mean Lumens
70W MH	90	4950

All the lighting calculations are performed using an IESNA Type III distribution "shoe box" luminaire with anodized hydroformed aluminum reflector, flat lens, and full cutoff optics. The distribution of the light from a Type III luminaire is an asymmetric oblong oval that is parallel to the edge of the sidewalk. This results in better uniformity on the sidewalk for a given luminaire spacing.

Hydroformed optics are used in sidewalk applications, and are moderate in performance and overall quality of light control. Segmented optics are typically the highest quality, followed by hydroformed, and finally refractor optics, which are generally the worst performers.

Many sidewalks designs utilize a non-cutoff style light fixture, often a globe or an acorn because of their decorative nature. These fixtures can be successfully used on sidewalks, but special care must be taken to ensure that the quality of the luminaire is sufficient to ensure a quality nighttime environment. Most of these globes or acorns have poor optics, are energy inefficient, and are a significant source of glare, light trespass, and light pollution, which make them unacceptable for use.

Lighting Models

The site lighting model is based on typical sidewalk dimensions found in commercial developments. The typical sidewalk is assumed to be 5 ft wide, with 15 ft lighting poles spaced from 60 ft to 90 ft apart. Table 14 shows the assumptions for each of the lighting zones.

Table 14 – Lighting Models – Building Grounds

Zone	Luminaire Type	Lamp	Pole Height	Pole Spacing
1	Type III	50W MH	15 ft	90 ft
2	Type III	50W MH	15 ft	80 ft
3	Type III	50W MH	15 ft	70 ft
4	Type III	50W MH	15 ft	60 ft

A typical sidewalk cross-section is formed, and the length is set to accommodate three luminaires down the length. The lighting calculations are performed across the entire sidewalk, from one pole to one-half the distance to the next pole, starting at the middle pole. Because of the symmetry and repetition in the lighting system, a small portion will represent the entire lighting design.

The LPD for the sidewalk is calculated based *only on the sidewalk square footage* for each particular cross-section, and covers the area one-half the distance from a pole to the next pole in both directions.

The LPD for the entire site is proposed to be the LPD for all the sidewalks on the property, plus an additional 20% allowance to accommodate the random landscaping and other site lighting that may not fall under any other category.

Pole heights for pedestrian walkways generally do not increase as the light level requirements of the sidewalk increase. Lamp wattages may increase with the higher light level criteria; however, this is not generally a requirement to meet the guidelines. The typical pole height and lamp wattage used are based on common combinations and are then adjusted to meet the lighting criteria for the particular lighting zone classification.

Calculations

All building grounds lighting calculations are performed using AGI-32 v1.50 by Lighting Analysts, Inc. AGI-32 is a lighting calculation program that will perform point-by-point calculations of exterior lighting designs based on the specification of the geometry, the luminaire information, and relevant lumen maintenance information for the model. Calculations can be performed for horizontal and vertical illuminance and luminance within a grid, and computation of uniformity ratios are provided for the calculations.

The luminaire dirt depreciation factor (LDD) used for the model is 0.7, which represents a dirty air environment typically found only near manufacturing facilities and in very dusty environments. For most applications, this will represent a conservative design approach.

The initial design for each sidewalk classification is selected based on common pole heights, lamp wattages, and pole spacing used for sidewalks considering the likely surrounding neighborhood conditions. This initial design is then modified based on the results of the calculations until the criteria are met.

The initial lighting criteria for roadway lighting design are average horizontal illuminance and minimum vertical illuminance. These are met by first adjusting the pole spacing to meet the guidelines. The horizontal illuminance ratio criterion is then checked to verify that it is satisfactory.

Table 15 – Lighting Calculations – Building Grounds

	LPD		Average Horizontal Illuminance		Minimum Vertical Illuminance		Horizontal Illuminance Ratio	
Zone	**Calculated**	**Recommended**	**Criteria**	**Calculated**	**Criteria**	**Calculated**	**Criteria**	**Calculated**
1	0.24	0.30	0.20	0.66	0.06	0.00	10:1	12:1
2	0.27	0.35	0.30	0.74	0.08	0.10	6:1	9:1
3	0.31	0.40	0.40	0.84	0.10	0.20	4:1	4.6:1
4	0.36	0.45	0.50	0.98	0.20	0.30	4:1	3.5:1

The results in Table 15 indicate that it is possible to meet the illuminance criteria, but not meet the uniformity criteria without drastic over-lighting of the sidewalk, or an increase in the mounting height of the luminaire and an increase in the lamp wattage. The reason for this is that the full cutoff light distribution of the luminaire minimizes the light that propagates out at small angle below horizontal. This results in a fairly confined circle of light on the ground below the luminaire. While this is very desirable in terms of the quality of light in the nighttime environment due to the reduced glare, light trespass, and light pollution, it has an impact on the environment. As the lighting criteria decrease (as the lighting zone decreases), it becomes increasingly difficult to meet the lighting criteria. The reason for this is that as the pole spacing increases, all of the criteria metrics get worse.

Recommendations

Definitions

Hardscape Area	An outdoor, paved, or unpaved nonresidential area, designed for or functioning as walkways, stairs, ramps, or plazas.
Lighted Hardscape Area	The physical horizontal projection of the walkway, ramp, stair, and/or plaza area that is lighted. Hardscape areas within 5 ft of the building perimeter and parking areas are not included. These are included in the entrances and façade lighting measures. The lighted area shall not extend beyond an area defined as 2.5 times the pole height.

Lighting Controls

Photosensor, programmable time clocks, or yearly astronomical controls will be required to turn off all pre-curfew lighting during daylight hours. Building grounds lighting will be required to turn off or be reduced during curfew, according to the environmental zone. Motion sensors may be required to turn off or reduce lighting power during curfew hours, according to environmental zones.

The allowed lighting power for building grounds illumination, in conjunction with each application for a building permit, shall be calculated according to Table 16 below.

Table 16 – Lighting Power Allowances – Building Grounds

	LZ1	LZ2	LZ3	LZ4
Building Grounds (walkways, plazas, stairs, and ramps)	0.30	0.35	0.40	0.45

Controls

Controls for the building grounds lighting in each lighting zone are listed below as the average percentage of building grounds lighting energized during this period.

Table 17 – Lighting Control Requirements – Building Grounds

	LZ1	LZ2	LZ3	LZ4
Walkway – Pre-Curfew	[llh25]100%	100%	100%	100%
Walkway – Post-Curfew	10%	50%	50%	50%
Stairs/Ramps – Pre-Curfew	100%	100%	100%	100%
Stairs/Ramps – Post-Curfew	100%	100%	100%	100%
Landscape Lighting – Pre-Curfew	0%	50%	100%	100%
Landscape Lighting – Post-Curfew	0%	0%	0%	50%
Recreation Sports Lighting – Pre-Curfew	0%	100%	100%	100%
Recreation Sports Lighting – Post-Curfew	0%	0%	0%	0%

Exempt Lighting

Normally-off lighting for emergency egress or accessibility as required by other portions of this code or other codes or ordinances.

Bibliography and Other Research

Illuminating Engineering Society of North America, RP-8-00 “American National Standard Practice for Roadway Lighting.” New York, NY: IESNA. 2000.

Illuminating Engineering Society of North America. IESNA Lighting Handbook, Ninth Edition. New York, NY: IESNA. 2000.

Measure 4 – Building Entrance and Entrance Canopies

Description

This measure sets maximum lighting power densities (LPDs) for building entrances with and without canopies. The purpose of the measure is to allow sufficient light for safety, adaptation compensation, or security needs, but not so much light that the exterior of the building is lighted to interior levels or will create glare problems beyond the entrance. The recommended lighting power allowances reflect good design practice and make use of cost effective, high efficacy lighting sources.

Lighting controls are also required for all entry areas, so that lighting power may be turned off or reduced after curfew. The standard does not require curfews, but does require controls that are capable of operating on a curfew schedule. An occupancy sensor that turns the entry lighting on when approached after curfew may be included, but such a sensor also requires a photosensor to ensure the lights remain off during the day.

A standard is also proposed for point of sale canopies (e.g., gas stations, etc.). The two standards are similar in structure, but are based on very different design criteria. Point of sale canopies have higher lighting power allowances. If a covered entry is contiguous with a point of sale canopy, it is important to distinguish where one area ends and the other begins.

Design Criteria

Building entrances and walkways under canopies are in the transition zone between the building interior, with a design illuminance from 20 to 70 footcandles, to parking lots or sidewalks, with a design illuminance of 0.5 to 2 footcandles. As a general guideline, the transitional lighting provided at building entrances should be approximately one-tenth to one-fourth of the interior illumination levels immediately inside the building, and/or 2 to 5 times the surrounding exterior illumination levels. This suggests that illumination levels for building entrance areas would range from a minimum of 2 footcandles to a maximum of 15 footcandles.

The lighting guide in the Illuminating Engineering Society of North America (IESNA) Handbook[5] specifies recommended horizontal and vertical illuminance for active and inactive entrances. These recommended illuminance levels are shown in Table 18 below.

Table 18 – IESNA Recommended Illuminance for Building Entrances (in footcandles)

Location/Task	Horizontal Illumination	Vertical Illumination
Active Entrances	5	3
Inactive Entrances	3	3

In some cases, security considerations determine the minimum light levels. The IESNA Lighting Handbook's security section recommends a 5 footcandle minimum illuminance on entries and sidewalks for convenience stores that stay open all night.[6]

Thus, the visual and security environment around an entry impacts the appropriate light level in the entry zone. In the intrinsically dark and rural zones (i.e., Lighting Zone 1 and LZ2), a low (i.e., 2 to 5 footcandle) design illuminance is used for calculating allowable lighting power densities. In urban areas (i.e., LZ3 and LZ4) with higher security needs and higher ambient illumination, a higher (i.e., 10 to 15 footcandle) design illuminance is used to determine the LPD for entries.

5 Illuminating Engineering Society of North America (IESNA) Handbook, Ninth Edition. p. Outdoor-1,

6 Ibid. pp. 29-21 to 29-22.

Lighting Equipment

Efficient light sources associated with canopy and entry lighting are assumed to have a minimum luminous efficacy of 55 mean lumens per watt in our analysis. A 70% overall light loss factor is used to account for the combination of surface and luminaire depreciation. Recessed downlights are assumed to be mounted at the canopy height with either flood or spot lamps.

Lighting Models

The following models are used in the analysis, with conservative assumptions for low reflectances of surfaces:

- Glazed storefront entrance (9 ft wide, 9 ft high), with a small canopy (approximately 4 ft deep, 9 ft wide, 9 ft overhead).
- Glazed storefront entrance (20 ft wide, 9 ft high), with an extended canopy over the walkway (approximately 10 ft deep, 50 ft wide, 12 ft overhead).
- Entrance with a large, covered drive-up entry (port cochere) or overhead structure (approximately 30 ft deep, 30 ft wide, 15 ft overhead).

Surrounding surfaces are assumed to have the following reflectances:

- Wall reflectance = 62%.
- Ceiling reflectance = 49%.
- Door and window reflectance = 25% (20 ft wide, 9 ft high).
- Ground reflectance = 7%.
- Reflectance of open areas = <2%.

Calculations

Entrances are modeled with the Lumen-Micro lighting software to assure that proposed LPDs provide sufficient horizontal and vertical illuminance as per the IESNA recommended design criteria described above.

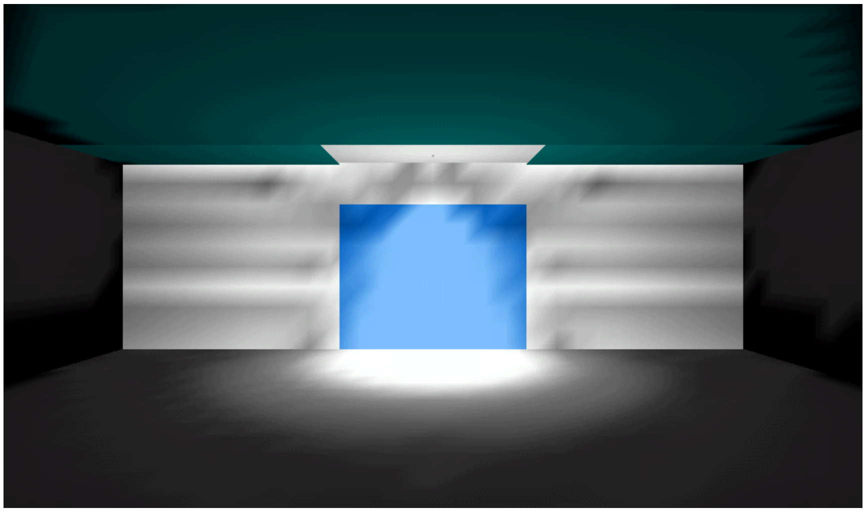

Figure 5 – 9 ft Wide Storefront Entrance with Small Canopy, 35W MH Flood

The recommendations are in terms of a lighting power allowance per unit area. The entry area is defined by either: 8 ft in front of the operable door(s) width, plus 3 ft on either side of the operable door(s); or the area under the entrance canopy. Thus, lighting is regulated in terms of LPDs in units of W/ft² of entry area.

Recommendations

Definitions

Entry	Any operable doorway in or out of a building, including overhead doors.
Canopy	A structure consisting of a waterproof roof and supporting building elements, with the area beneath at least partially open to the elements. A canopy may be freestanding or attached to surrounding structures.
Entrance Canopy	A canopy attached to a building, and leading to a building entrance.
Under-Canopy Area	The horizontal plane projected beneath the edges of the canopy roof.
Entry Area	The larger of: 1) 8 ft in front of the operable door(s) width, plus 3 ft on either side of the operable door(s); or 2) the area under the entrance canopy.

Lighting Power

The allowed LPD for exterior entrance lighting shall be no greater than the figures contained in Table 19. Areas falling under more than one definition may use the higher LPD, but may not be counted more than once in any the exterior lighting power allowance.

Exterior lighting is required to have timeclock controls for curfew shutoff, as specified in Table 19 below. These requirements are in addition to the Section 131(f) control requirements. If an occupancy sensor is added to turn on the entry lights when someone approaches the door after curfew, a photocontrol must also be added to ensure that the light remains off during the daytime.

Table 19 – Entry Area Exterior Lighting Power Allowances, in Lighting Power Density (W/ft^2) and Control Requirements

Description	LZ1	LZ2	LZ3	LZ4
Entry Area	0.50	0.05	1.00	1.50
Timeclock Controls	Required	Required	Required	Required
Occupancy Sensor with Photocontrol	Not allowed for curfew compliance	Optional for curfew compliance	Optional for curfew compliance	Optional for curfew compliance
Bi-Level Illumination at 50% of Output	Not allowed for curfew compliance	Not allowed for curfew compliance	Optional for curfew compliance	Optional for curfew compliance

Exception

Lighting used for the entrance to emergency rooms or hospitals is exempted from these requirements.

Bibliography

Illuminating Engineering Society of North America. IESNA Lighting Handbook, Ninth Edition. New York: IESNA. 2000.

American Society of Heating Refrigerating and Air-conditioning Engineers. ASHRAE Standard 90.1-1999. Atlanta, GA: ASHRAE. 1999.

Washington State Nonresidential Energy Code.

Oregon Office of Energy Lighting Code Change. Proposal dated January 16, 2002.

Measure 5 – Building Façades

Description

This measure expands the scope of the Title 24 building energy efficiency standards to include building façade lighting, such as prescriptive lighting power density (LPD) and mandatory lighting control requirements. The requirements vary with outdoor lighting zones. This provides a way to compensate for sites with significantly different ambient light conditions. The recommended lighting power ranges from 0.00 in Lighting Zone (LZ) 1 to 0.50 in LZ4.

Additional control requirements are also recommended. Besides the photocell or timeclock already required by §131(f), a timeclock must be provided to turn off or reduce lighting for curfew hours. The lighting control must also be capable of reducing lighting to 50% of full power during curfew.

The 60 lumens per watt (LPW) efficacy requirement of §130(c) applies to all outdoor facade lighting with lamps larger than 100 W.

The lighting power allowance is intended only for façade lighting. As such, it is not allowed for trading with any other power allowance, indoor or outdoor. If a façade is not lighted, then no power allowance is available for that façade, similar to the "use-it-or-lose-it" criteria for existing interior lighting energy standards.

Design Criteria

The Illuminating Engineering Society of North America (IESNA) recommends design conditions in RP-33-99 and the IESNA Lighting Handbook, Ninth Edition. IESNA has a range of illuminance recommendations for façades, based on the brightness of the surrounding area and also the general reflectance of the façade. Models include a range of illuminance levels, representative of three outdoor lighting zones.

Historical Illumination Recommendations and Existing Typical Examples

Historically, IESNA-recommended façade illuminance levels were higher than current recommendations. For example, in the IESNA Lighting Handbook, Fifth Edition (effective in the 1970s) recommendations ranged from 5 to 20 footcandles for dark surroundings and 15 to 50 footcandles for bright surroundings. Some lighting manufacturers may still suggest these vintage recommended illumination levels in their literature. IESNA revised their recommended façade illumination levels with RP-33-99, Lighting for Exterior Environments, and in the Lighting Handbook, Ninth Edition (published in 2000).

Some manufacturers provide examples of façade illumination using their products. For example, one company recommends 175-W metal halide (MH) floodlights to illuminate a 100 ft long by 35 ft tall façade to an average of 12.62 footcandles. The LPD is 0.54 W/ft^2. If this same façade were illuminated to the current IESNA recommendation of an average of 5 footcandles, the calculated LPD would be 0.21 W/ft^2.

Another manufacturer offers a linear luminaire that uses a 28-W T5 lamp. They suggest that 28-W lamp luminaires, mounted end to end, will illuminate a 12-ft tall façade to 25 footcandles with an LPD of (7.7 W/lin ft divided by 12 ft equals) 0.64 W/ft^2. Prorating this illuminance to 5 footcandles yields a reduction in LPD to 0.13 W/ft^2.

Table 20 – Illuminance Levels for Floodlighting Buildings and Monuments

Area Description	Average Target Illuminance Footcandles
Bright Surroundings and Light Surfaces	5
Bright Surroundings and Medium Light Surfaces	7
Bright Surroundings and Dark Surfaces	10
Dark Surroundings and Light Surfaces	2
Dark Surroundings and Medium Light Surfaces	3
Dark Surroundings and Medium Dark Surfaces	4
Dark Surroundings and Dark Surfaces	5

Source: IESNA RP-33-99 *recommends the following façade illuminance (page 30)*

The IESNA Lighting Handbook, Ninth Edition, recommends the same illumination levels for facades as RP-33-99, except that it adds a level of 10 footcandles for Bright Surroundings and Medium Dark Surfaces, and then changes the recommendation for Bright Surroundings and Dark Surfaces to 15 footcandles.

Establishing Typical Façade Illuminance

Establishing proper façade illuminance for each outdoor lighting zone requires consideration of the typical lighting needs expected for each zone. Also, the selected illuminance makes a difference in the LPD result from each model.

Table 21 – Target Illuminance Levels for Models

Lighting Zone	Description	Target Illumination Levels
1	Dark, critical zone	No façade lighting
2	Dark surroundings with medium light surfaces	3 footcandles
3	Bright surroundings with light surfaces	5 footcandles
4	Bright surroundings and medium dark surfaces	10 footcandles

These target illumination levels were selected with the view that an architect will select somewhat lighter colored façade surfaces if the plan is to illuminate; dark surfaces simply provide less-bright façades than do light surfaces. The IESNA Lighting Handbook recommends the highest illumination in areas like LZ4, featuring very bright night activities such as a central downtown metropolitan area that remains active 24 hours each day.

A conservative light loss factor of 0.70 is selected for the models, in addition to using mean lamp lumen ratings in the computations.

Lighting Equipment

Light Sources

Light sources for the models are compact fluorescent, fluorescent, and MH lamps. High-pressure sodium (HPS) lamps may also be a good light source, but they always produce more light than a MH lamp of the same power. Therefore, an LPD that works for MH also works with HPS lamps. Table 22 shows the lamp types considered in the models, including some small lamp types that may be used for outdoor floodlighting such as small compact fluorescent, at 45 mean lumens per watt (MLPW), and small MH, at 50 MLPW. All metal halide (MH) lamps used in the models are pulse start (all available MH lamps smaller than 175 W currently utilize pulse start technology).

Table 22 – Façade Lighting Calculations Lamp Types and Mean Lumens

Source Codes	Lamp Types	Mean Lumens Per Watt (MLPW)
1	Incandescent	10
2	Small CFL	45
3	Halogen IR	20
4	Compact Fluorescent	55
5	Biax/T5HO	75
6	T8/T5	90
7	Small Metal Halide	50
8	Pulse start metal halide	75
9	Other	70

Floodlight luminaires were selected that utilize the selected compact fluorescent, linear fluorescent and MH sources. As shown in the models, the luminaire size and light distribution varies depending on the façade dimensions and luminaire setback, as usual in a façade lighting design.

Sconce luminaires are typically used for decorative lighting rather than illumination. The proposed standards do not preclude the use of sconces for façade lighting, so long as they do not exceed the LPD and other requirements.

Outdoor luminaires often have cutoff classifications determined by their optical systems and mounting, as indicated by IESNA (see RP-33-99, chapter 8). Some façade lighting arrangements, however, preclude use of these classifications; therefore this standard does not designate any cutoff classifications for façade lighting. The lighting designer must use proper judgment to make sure that specified façade lighting does not create inappropriate light trespass, light pollution, or glare.

Lighting Models

Several models are developed to explore appropriate lighting power allowances. Each model assumes typical façade dimensions, utilizing appropriate floodlight luminaires and lamps in a typical mounting arrangement. The average illuminance is then computed based on coefficients of beam utilization to verify compliance to the selected recommendations. Although a relatively uniform façade illuminance is built into these models, typical current lighting design highlights façade elements, instead of flooding an entire façade surface with light. This practice means that these models are conservative for façade lighting design.

Table 23 – Outdoor Façade Lighting Model Factors

Lighting Zone	Lamp Type	Façade Illuminance (footcandles)	Façade Dimensions (ft wide x ft tall)	Recommended LPD (W/ft^2)
2	Compact Fluorescent	3	75 x 9	0.18
2	28 W T-5	3	75 x 12	0.18
3	28 W T-5	5	75 x 12	0.30
3	Metal Halide	5	75 x 12	0.30
3	Metal Halide	5	150 x 35	0.30
4	Metal Halide	10	75 x 12	0.50
4	Metal Halide	10	150 x 48	0.50

The modeling calculation spreadsheet is developed from, and is similar to, the modeling spreadsheet used in the 2005 Title 24 update for indoor lighting power allowances. Some of the parameters for indoor lighting (e.g., wall, floor, and ceiling reflectances; coefficient of luminaire utilization; luminaire classification; and room cavity ratio) are not required for outdoor lighting. A new outdoor lighting factor, coefficient of beam utilization, is added. As mentioned above, small compact fluorescent and small MH light sources are new model options.

- Light Level = the design illuminances for the modeled facade.

- Light Loss Factor represents the sum of the light depreciating factors (maintenance factor), less the lamp lumen depreciation, which is included in the mean lamp lumen rating. The IESNA Lighting Handbook, Ninth Edition, recommends light levels and light loss factors used in these models.
- Under the Lighting Systems heading, details include lamp (e.g., rated at mean lumens, output at 40% of rated lamp life) and luminaire information, percent of total light provided by each lighting system, and the coefficient of beam utilization (CBU) for each luminaire specified.
- Under the Calculations heading:
  - The lumens required from each lighting system and the lamp power needed to provide those lumens for each system are listed.
  - Net Lumens = maintained light necessary to provide specified illumination, shown as both a total of all systems and for individual systems.
  - Gross Lumens = light before applying the CBU.
  - Lamp Lumens = Gross Lumens before applying the light loss factor.
  - Minimum Theoretical Watts = the sum of total lamp power needed from each lighting system.
  - Minimum Theoretical Power Density = the quotient of the Minimum Theoretical Watts divided by the space area.
- Recommended Value for Standard (e.g., allowable lighting power, W/ft^2) is the Minimum Theoretical Power Density rounded up to provide some design flexibility.

Calculations

The seven new models developed for façade lighting provide the results shown in Table 24:

Table 24 – Outdoor Façade Lighting Model Factors

Lighting Zone	Lamp Type	Façade Illuminance (fc)	Façade Size (ft wide x ft tall)	Required Flux (Lumens)	Minimum Computed Power (Watts)	Recommended LPD (W/ft^2)
2	Compact Fluorescent	3	75 x 9	2025	122	0.18
2	28 W T5	3	75 x 12	2700	143	0.18
3	28 W T5	5	75 x 12	4500	179	0.30
3	Metal Halide	5	75 x 12	4500	268	0.30
3	Metal Halide	5	150 x 35	26250	1563	0.30
4	Metal Halide	10	75 x 12	9000	451	0.50
4	Metal Halide	10	150 x 48	72000	3189	0.50

Recommendations

Provisions

This proposal recommends maximum power allowances for outdoor façade lighting, based on outdoor lighting zones, as outlined in Table 25 below.

Table 25 -- Lighting Power Allowances for Building Facades

Outdoor Lighting Zone	Maximum Lighting Power Density (W/ft^2)
1	0.00
2	0.18
3	0.30
4	0.50

Lighted Area and Calculating Allowed Lighting Power

A key component of using lighting power density is to determine a valid lighted area. The lighted area, coupled with LPD, provides the lighting designer with the allowed lighting power. The models use the entire façade for lighted area. However, only areas of a façade intentionally lit are considered as lighted areas.

Should a lighting designer leave any façade unlit, that is, without a luminaire intentionally aimed at it or a façade sconce mounted on it, that façade cannot be included in the façade lighting power allowances. By the same token, if the lighting designer leaves parts of a lighted façade without lighting, then only the lighted parts of the façade can be used to compute lighted area. The total lighted area used in LPD computations is the sum of the lighted areas included in each lighted façade.

Computing the lighted area of a façade that is a planar surface is a matter of geometry. If a façade is an irregular surface in three dimensions, compute the lighted area from the façade components that face the luminaire. For example, if a luminaire is west facing (see Section §101: Definitions), the parts of a façade that are east facing and can be illuminated by the façade lighting constitute the lighted façade area.

A lighted roof is included as a separate façade; include only the geometric area of the lighted roof section for lighted area in power allowance calculations.

Lighting Controls

Title 24 already mandates controls to turnoff outdoor lighting during daylight hours. This proposal recommends an additional mandatory requirement that at least one-half of the outdoor lighting incorporate a timer or timeclock that allows outdoor lighting to be turned off during non-business hours or other curfew period. This could be the control otherwise mandated, if the building owner wants to control all facade lighting this way.

This new control requirement supports the California Governor's Executive Order D-19-01, which requires retail establishments to substantially reduce outdoor lighting during non-business hours. It also permits simple compliance with other curfew needs, and could assist in any other state or utility energy saving incentive program or mandate.

Bibliography and Other Research

American Society of Heating, Refrigerating and Air-Conditioning Engineers. Lighting power density models for ASHRAE/IESNA 90.1-1999 Standard. From web site: http://206.55.31.90/cgi-bin/lpd/lpdhome.pl.

California Energy Commission. Lighting power density models for 2005 nonresidential lighting standards.

Davis, Gray. California Executive Order D-19-01. See http://www.energy.ca.gov/efficiency/lighting/outdoor_reduction.html.

Illuminating Engineering Society of North America. Lighting for Exterior Environments, RP-33-99, New York, NY: IESNA. 1999.

Illuminating Engineering Society of North America. Lighting Handbook, Ninth Edition. New York, NY: IESNA. 2000.

Illuminating Engineering Society of North America. Lighting Handbook, Fifth Edition. New York, NY: IESNA. 1972.

New Buildings Institute. Advanced Lighting Guidelines 2001. White Salmon, WA: NBI. 2001.

Measure 6 – Outdoor Sales Canopies

Description

This proposed standard would set the maximum lighting power for outdoor sales canopies[7]. This includes covered points of sale such as service station canopies or fruit stands. The recommended standards include a limit on lighting power, shielding requirements for luminaires over 100 W, and minimum control requirements.

Design Criteria

The Illuminating Engineering Society of North America (IESNA) design criteria for sales canopies are shown in Table 26 and Table 27. Both tables have recommendations for two conditions: "dark surroundings" and "light surroundings." The values for "light surroundings" are used for the Lighting Zone (LZ) 3 design criteria and the values for a "dark surroundings" are used for LZ2. For LZ1, the "dark surroundings" value for pump islands is used.

The design criteria for LZ3 and gas stations are used for light modeling and the results for the other conditions are scaled according to the design illuminances shown in Table 28.

Table 26 – IESNA Design Criteria – Service Station and Gas Pump Areas

		Footcandles	
		Dark Surroundings	**Light Surroundings**
Gas Stations	Approach	1.5	2
	Driveway	1.5	2
	Pump Island	5	10
	Building Façade	2	3
	Service Areas	2	3
	Landscape Highlights	1	2

Source: IESNA Handbook Figure 17-20 Service Station or Gas Station Area Average Illuminance Levels

Table 27 – IESNA Design Criteria – Service Station

	Footcandles			
	Dark Surrounding		**Light Surrounding**	
	Horizontal	**Vertical**	**Horizontal**	**Vertical**
Approach	1.5	0.5	2	0.5
Driveway	1.5	0.5	2	0.5
Pump Island Area	3	3	5	3
Building Faces (exclusive of glass)	2	0.5	3	3
Service Areas	2	0.5	3	3
Landscape Highlights	1	0.3	2	0.5

Source: IESNA Handbook 9th Edition Design Guide

7 A sales canopy has a roof but no walls and is not considered an interior space.

Table 28 – Design Criteria for Sales Canopies
Note: These data are used as the basis of the proposed standard.

	Horizontal Illumination (footcandles)			
	LZ1	**LZ2**	**LZ3**	**LZ4**
Gas Station Canopies	5.	10	20	40
Other Sales Canopies	2.5	5	10	20

Lighting Equipment

The following lighting technologies were used in the lighting models used to calculate the allowed lighting power density (LPD).

1. The metal halide (MH) "pulse start" lamp.
2. Compact fluorescent lamps including T-5 twin tube lamps, T-4/T-5 triple tube amalgam lamps, and electronic ballasts.
3. To a limited extent, high-pressure sodium (HPS) lamps. Inferior color rendering tends to limit HPS lamp use to non-retail, non-critical applications.

Outdoor lighting under canopies generally requires good color rendering for which MH and fluorescent lamps are suitable. MH pulse start technology is now widely available in lamps rated 20 W to 2000 W, and specifically available in all useful lamp ratings in the range of 39 W to 400 W in which most under canopy lighting is expected to be designed. Compact fluorescent triple tube amalgam lamps (18 W to 57 W) and compact fluorescent T-5 twin lamps are also useable for exterior lighting. In some cases, HPS lamps might also be used where color is not an issue.

The following table shows the assumed performance of pulse start MH lamps and comparable HPS and fluorescent lamps.

Table 29 – Lamp Performance Data – Outdoor Canopies

Lamp Watts	Lamp Type	Lumens		Input Watts	Lumens per watt		Life (hours)
		Initial	**Mean**		**Initial**	**Mean**	
32	PL-T (Compact Fl)	2400	2064	35	69	59	10000
40	PL-L or Biax T-5	3150	2775	37	86	76	20000
70	HPS Hg Free	6000	5100	86	70	59	20000
150	HPS Hg Free	15500	13200	180	86	73	20000
150	Pulse Start MH	12900	10000	180	72	56	15000
100	Pulse Start MH	8500	5525	122	70	45	15000
100	Pulse St MH Electronic ballast	8500	5750	112	76	51	15000

Source: www.sylvania.com.

All of these lamps are available from U.S. and international lamp companies, and are standard offerings from most luminaire manufacturers. According to one direct mail order company (RUUD Lighting), there is almost no cost difference between pulse start and probe start MH luminaires.

Fifty-five mean lumens per watt (MLPW) is the recommended source value for calculating allowed LPD.

Modeling done for the Advanced Lighting Guidelines shows that using T-5 twin tube lamps results in higher light levels than MH due to the superior efficacy of the compact fluorescent. The 150-W class pulse start MH achieves 56 MLPW, versus 76 for the T-5 twin. However, the T-5 twin is susceptible to temperature sensitivity making it a questionable choice in parts of California. Thus the decision to use the MH for code purposes was made.

Lighting Models

Lighting calculations were performed for one model shown in Figure 6, with the results used for LZ3.

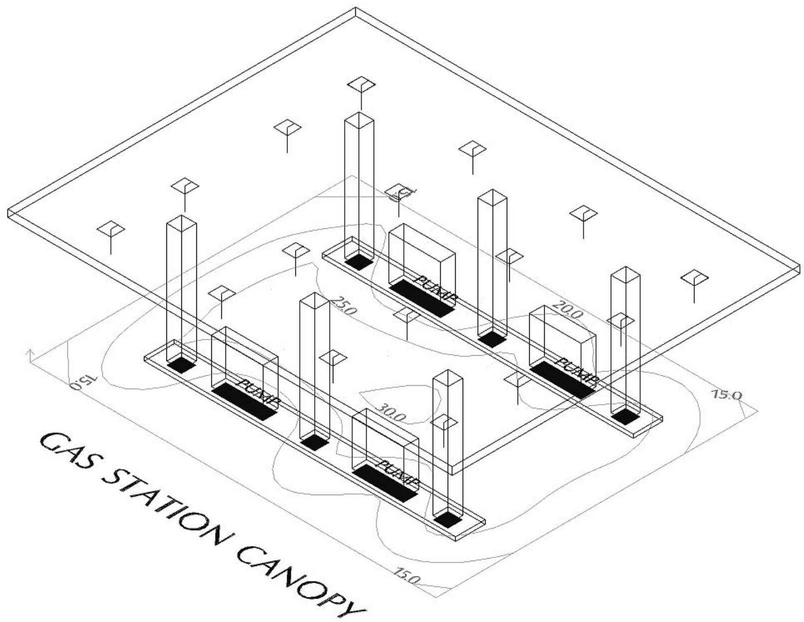

Figure 6 – Lighting Model – Service Station Canopy

Calculations

Calculations use MLPW and an additional overall light loss factor of 0.70. This eliminates specific ballast factor and other complications from the process and addresses lumen depreciation issues correctly. This design uses 150-W MH lamps to achieve a mean, maintained average of over 20 footcandles with extremely uniform illumination that contributes to the surrounding lot as well. The luminaire is a flat lens 2x2 downlight unit, Lithonia G1 series. The connected power is 1.25 W/ft² of canopy area.

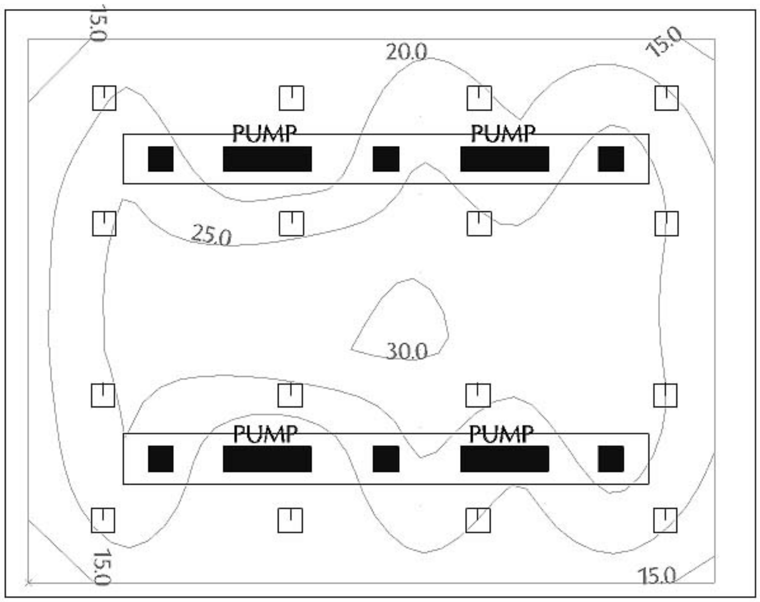

Figure 7 – Lighting Calculations – Service Station Canopy

Recommendations

Definitions

Canopy	A structure consisting of a roof and supporting building elements, with the area beneath not enclosed or partially enclosed by roof-high walls but remaining at least partially open to the elements. A canopy may be freestanding or attached to surrounding structures. Note: the canopy “roof” may serve as the floor of a structure above.
Under-Canopy Area	The area under a canopy enclosed by supporting walls, adjacent structure walls and/or if no wall is present, by the vertical plane projected to the surface or grade from the edge of the canopy roof.

Provisions

For lighting under canopies, the allowed lighting power for **feature and display lighting** under exterior canopies shall be the smaller of:

- The product of the area under each canopy and the allowed LPD according to lighting zone, as listed in Table 30. .
- The actual lighting power used for under-canopy lighting.

Table 30 – Recommended Lighting Power Allowances – Point of Sale Canopies

	Allowed LPD			
Canopy Type	**LZ1**	**LZ2**	**LZ3**	**LZ4**
Retail Gas and Service Stations (W/ft^2)	.33*	.67*	1.25	2.50
Other Vehicle Service Stations (W/ft^2)	Not allowed	.33*	.67	1.25
Covered Outdoor Sales (W/ft^2)	Not allowed	.33*	.67	1.25

* Must be extinguished upon close of business.

Exempt Lighting

- Lighting within water features or pools governed by Article 680 of the California Electrical Code.
- Normally-off lighting for emergency egress or accessibility as required by other portions of this code or other codes or ordinances.
- The portion of sports lighting systems for illumination of the field and aerial play.

Bibliography and Other Research

Illuminating Engineering Society of North America. IESNA Lighting Handbook, Ninth Edition. New York, NY: IESNA. 2000.

Measure 7 – Outdoor Sales Areas

Description

This measure restricts the wattage of lighting permitted for outdoor sales areas not covered by canopies or other shelters. This includes automobile sales lots, outdoor construction materials sales lots, and outdoor activity areas such as miniature golf, family fun centers, and permanent swap meets. In addition, special attention is given to preserve the needs of outdoor feature lighting (except signs).

The recommended standard includes maximum allowed power densities for two classes of outdoor sales: vehicle sales lots and other outdoor sales. The basic lighting power allowance for lots would be permitted to be traded off among site parking, drives, walks, canopies, and other allowances.

In addition to the basic lighting allowance, an additional allowance is provided for the portion of the sales area adjacent the roadway. This allowance can only be used for display lighting of vehicles or other merchandise along the frontage road. Lighting power densities (LPDs) are recommended for LZ2, LZ3, and LZ4, but not LZ1. In LZ1, outdoor sales should not be permitted. All of the outdoor display allowance is “use-it-or-lose-it.”

In addition to the power allowances, luminaires with lamps greater than 100 W must be of the cutoff type as defined by the Illuminating Engineering Society of North America (IESNA). Lighting controls would be required to reduce or eliminate lighting after business hours or curfew.

Lighting shall have a photoelectric or astronomic time device to turn lighting off during the day. This requirement already exists in §131(f) of the standard. In addition, all outdoor display lights shall be reduced to 50% power after business hours by dimming and/or alternate luminaire switching. It shall be permissible to maintain frontage lighting at 100%, provided that the total power of the lighting for the frontage lighting and sales lot is reduced by at least 50%.

These standards would be enforced through the plan checking and compliance forms process already employed in Title 24. A prescriptive requirement similar to the Tailored Method would be used in which there is a basic allowance and a “use-it-or-lose-it” additional allowance for feature displays (e.g., retail).

Design Criteria

For outdoor sales, the IESNA design criteria for car dealerships differentiates the “front row” of automobiles and feature automobiles from “other rows” of automobiles. See Table 31 and Table 32.

For LZ3, a design illuminance of 10 footcandles is selected for the main outdoor sales area, with 20 footcandles for the street frontage portion of the sales area. These values are doubled for LZ4 and halved for LZ2. The recommended illuminance values are shown Table 33. The LZ3 values are used for light modeling and the resulting LPDs are scaled according to the relative horizontal illuminance values. Outdoor sales lighting is not recommended for LZ1.

In reviewing the data below, the pump island recommendations for open gas stations match the values recommended in Table 33. This means that the criteria developed for car dealerships can be used for open gas stations as well. Likewise, the highest outdoor light level recommendation for any other outdoor lighting task is illuminance category “C” (10 footcandles). This means that the criteria developed for car dealerships may be used for all outdoor sales activities.

Table 31 – IESNA Design Criteria – Car Dealerships

		Main Business Districts (highly competitive)		Secondary Business Districts or Small Towns	
		Footcandles	**Maximum/Minimum Ratio**	**Footcandles**	**Maximum/Minimum Ratio**
Car Dealerships	Front Row of Autos	10-20	5:1	5-10	5:1
	Feature Autos	10-20	5:1	5-10	5:1
	Other Rows	5-10	10:1	2.5-5	10:1
	Entrances	5-10	5:1	2.5-5	5:1
	Driveways	2-3	10:1	1-2	10:1

Source: IESNA Handbook Figure 17-18 Illuminance Levels and Uniformities for Car Dealerships

Table 32 – IESNA Design Criteria – Retail Spaces Outdoors

		Illumination (footcandles)	
		Horizontal	**Vertical**
Fast Food Restaurants		10	3
Car Dealerships — Business District	Front Row — Adjacent to Roadway	10	3
Car Dealerships — Small Towns	Front Row — Adjacent to Roadway	5	3
Convenience Stores		3	3
Pedestrian Mall		3	3

Source: IESNA Handbook 9th Edition Design Guide

Table 33 – Design Criteria for Outdoor Sales
Note: These data are used as the basis of the proposed standard.

	Horizontal Illumination (footcandles)			
	LZ1	**LZ2**	**LZ3**	**LZ4**
Display Frontage	n. a.	10	20	40
Outdoor Sales	n. a.	5	10	20

Lighting Equipment

The measure is based on the following lighting technologies

1. The metal halide (MH) “pulse start” lamp.
2. Compact fluorescent lamps including T-5 twin tube lamps, T-4/T-5 triple tube amalgam lamps, and electronic ballasts.
3. To a limited extent, high-pressure sodium (HPS) lamps. Inferior color rendering tends to limit HPS uses to non-retail, non-critical applications.

Outdoor sales lighting generally requires good color rendering for which MH and fluorescent lamps are suitable. MH pulse start technology is now widely available in lamps rated 20 W to 2000 W, and specifically available in all useful lamp ratings in the range of 39W to 400 W in which most under-canopy lighting is expected to be designed. Compact fluorescent, triple tube amalgam lamps (18 W to 57 W) and compact fluorescent, T-5 twin lamps are also appropriate for exterior lighting. In some cases, HPS lamps might also be used where color is not an issue. Please refer to Table 29 for additional information about lamp performance.

All of these lamps are commonly available from U.S. and international lamp companies, and are standard offerings from most luminaire manufacturers. According to one direct mail order company (RUUD Lighting), almost no cost difference exists between pulse start and probe start MH luminaires.

Fifty-five mean lumens per watt (MLPW) is recommended as the source efficacy for calculating allowed LPD.

Lighting Models

A lighting model is assumed to be 200 ft by 200 ft with a 5 x 5 grid of pole mounted luminaires. The front row has a series of poles (seven total), and each pole has multiple luminaires. All luminaires are 400 W Lithonia Boulevard with the forward throw distribution. See Figure 8 for details of the plan.

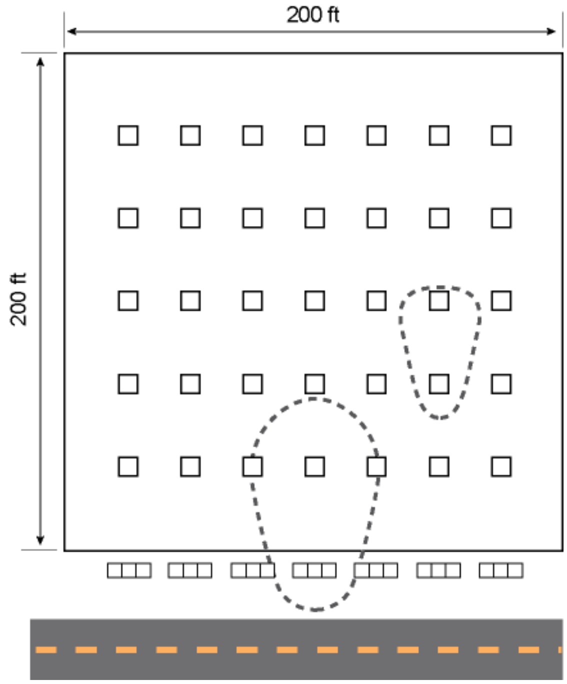

Figure 8 – Lighting Model – Vehicle Sales Area

Calculations

The lighting model is calculated using Lumen Micro 2000. Calculations are based on 55 MLPW and an additional overall light loss factor of 0.70. This eliminates specific ballast factor and other complications from the process and addresses lumen depreciation issues correctly.

The front row area is shown crosshatched in Figure 9. Light levels throughout the front row area are generally in excess of 20 footcandles. These are mean calculations without dirt depreciation. Allowing for maintenance factors other than lamp lumen depreciation (LLD), this design maintains at least 15 footcandles or better at the front row of bumpers. The front row of bumpers is assumed to be 10 ft above the poles to allow for vertical illumination. This model results in 42 400-W general illumination luminaires and 14 additional front row luminaires. The lot is 200 ft x 200 ft translating into .4809 W/ft^2 plus 32.06 W/lf. It is suggested that .5 W/ft^2 and 35 W/lf be used.

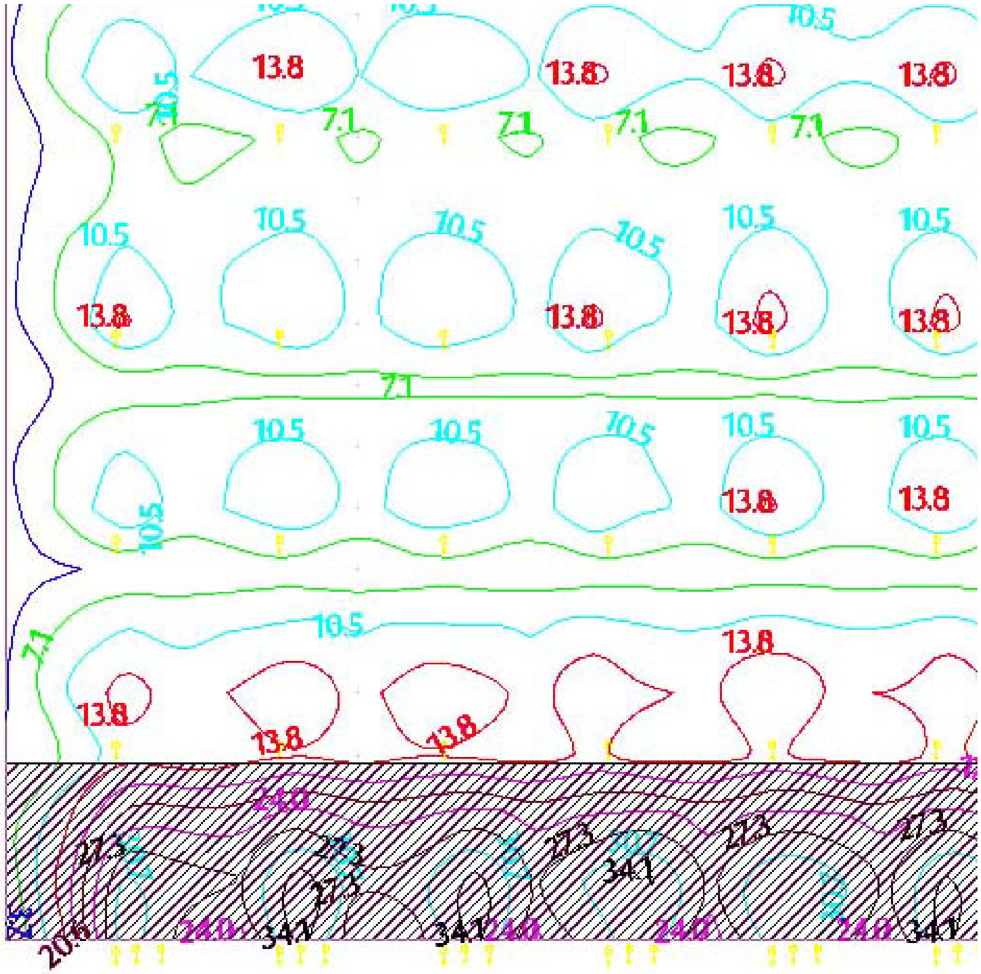

Figure 9 – Lighting Calculations – Outdoor Sales

These lighting values are calculated for LZ3 with a design criteria of 10 footcandles in the back of the sales area and 20 footcandles on the frontage.

This design satisfies the highest recommended light levels according to current IESNA recommendations. The results of this modeling are used as the basis of the LZ3 recommended power allowance. LZ2 lighting power is half that for LZ3 (based on assuming dark surroundings) and the LZ4 illumination is assumed to be twice that of LZ3. Outdoor retail lighting should be restricted in LZ1.

Recommendations

Definitions

Frontage — The portion of the perimeter of an outdoor sales area facing a street, road, or public sidewalk. For individual displays, such as an auto ramp, the frontage shall be two times the actual width of the display as measured in the vertical plane parallel to the street, road, or sidewalk.

Lighting Power

For each of the following exterior lighting applications, calculate the allowed power for **feature and display lighting** as indicated. The allowed power shall only be used for the specific lighting application for which it is calculated.

1. For outdoor sales areas, the allowed lighting power for feature and display lighting shall be the smallest of:
   a. The product of the allowed area and the associated display LPD.
   b. The actual lighting power used for feature and display lighting.
2. In addition, for each lineal foot of sales lot frontage, the allowed lighting power for frontage display lighting shall be the smaller of:
   a. The product of the allowed frontage and the associated display LPD.
   b. The actual lighting power used for feature and display lighting.

Table 34 – Recommended Lighting Power – Outdoor Sales
Note: Values are W/ft² unless otherwise indicated

Sales Area	LZ1	LZ2	LZ3	LZ4
Outdoor Sales	Not allowed	0.25	0.50	1.00
Auto Frontage	Not allowed	17.5 W/ft	35 W/ft	70 W/ft

Bibliography and Other Research

Illuminating Engineering Society of North America. IESNA Lighting Handbook, Ninth Edition. New York, NY: IESNA. 2000.

Measure 8 – Outdoor Signs and Billboards

Description

This measure would set maximum allowed power, minimum efficacy and control requirements for outdoor signs used for other than traffic regulation or emergency purposes. The measure identifies two basic types of outdoor signs, and designates different requirements for each type.

- **Externally Illuminated Signs**. This includes billboards and other signs that reflect light off of the viewing surface. Provisions for externally illuminated signs include a minimum source efficacy, maximum lighting power, and control requirements to turn the lights off during the day and after curfew. These requirements vary by lighting zone.
- **Internally Illuminated Signs**. This includes any sign where the light is seen directly by the viewer, or where it is bounced around inside of the sign and then transmitted through a filtering medium, lens, or open aperture. Provisions for internally illuminated signs include lighting power; minimum source efficacy; minimum reflectance for internal surfaces; a requirement that the background be opaque and the message area translucent (as opposed to visa versa); and control requirements to turn the lights off during the day and after curfew. The measures distinguish between three types of internally illuminated signs:
    - Panel signs, also called cabinet signs;
    - Channel signs, where the illuminated letters form the sign, and;
    - Unfiltered signs, where the light source is directly visible (e.g., neon).

Power allowances are recommended for all externally illuminated signs and internally illuminated panel signs, but not for channel signs and unfiltered signs. A minimum efficacy is set for any lamp that consumes more than 5 W. In addition, any sign that is illuminated during the daytime must be controlled to allow it to be dimmed to 50% light output at night. Illuminated signs with a connected load of more than 20 W are not allowed in Lighting Zone (LZ) 1.

Some of the sign provisions may overlap with the façade lighting requirements, if the façade presents an advertising message or image. Signs posted inside buildings are not currently regulated, but rather treated as plug loads.

Research Approach

The approach used to develop the standards for billboards and signs is different from the approach taken for other outdoor lighting measures. The approach for signs is to survey manufacturers recommendations for sign illumination. The criteria for LZ4 is set to the highest lighting level recommended by any of the manufacturers. The criteria for LZ3 is set at the 75^{th} percentile of the range of lighting power. The criteria for LZ2 is set to 50% of the LZ3 level. Power for signs in LZ1 are limited to less than 20 W per face.

The following bullets describe the research that is conducted to determine lighting power ranges for signs:

- Manufacturer's web sites are reviewed for current recommendations of source wattage relative to sign types and sizes. The web sites included Holophane, Wagner Electric, Adaptive, Electric Brite, Neon Central, and Acuity Brands.
- Association web sites were reviewed, including California Electric Sign Association, Outdoor Advertising Association of America, International Dark Sky Association, and Sign Web.
- The current Illuminating Engineering Society of North America (IESNA) Handbook, Ninth edition, discusses several objectives and methods for lighting signs.
- IESNA RP-19-01 includes a discussion of visual performance recommendations and pros and cons of various illuminated sign approaches.

- Building department personnel were interviewed relative to current regulatory practices affecting outdoor illuminated signs and the enforceability of various regulatory approaches.
- Other codes that regulate outdoor illuminated signs were reviewed, in particular El Monte, CA; and Flagstaff, Tucson, and Pima County, AZ.

Design Criteria

Illumination calculations for externally illuminated signs were based on current standard practice for sign sizes, reflectances, distance of luminaire from sign, full cut-off luminaires such that no significant illumination passes beyond the sign area, and top mounted luminaires that significantly reduce the dirt depreciation factor[8]. Design criteria are based primarily on manufacturers recommendations.

Lighting Equipment

Equipment selection can vary greatly for sign lighting. The following good practice provides the basis of the recommended standards.

1) Efficient sources appropriate for illumination of outdoor signs.
   a) Metal halide lamps for externally illuminated signs, with a minimum efficacy of 55 mean lumens per watt (MLPW).
   b) Fluorescent lamps for internally illuminated panel signs, with a minimum efficacy of 70 MLPW.
   c) Neon lamps for internally illuminated channel signs, with a minimum efficacy of 25 MLPW, and for direct neon signs.
   d) LED and incandescent sources less than 5 W per lamp are allowed for any other types of signs.
2) Automatic controls that can reduce the power and or the time of use of the outdoor signs.
   a) Require controls to reduce illumination levels by at least 50% at night for signs that are illuminated during the day, since less light is needed for legibility at night under lower ambient light conditions.
   b) Require controls that can turn off signs during the daytime, when illumination is not needed.
   c) Require controls that can automatically shut off lights on signs after curfew, or during power emergencies.
3) Good illumination engineering practice in the design of outdoor signs.
   a) Require reflective surfaces inside of internally illuminated signs, equivalent to a simple white enamel surface, to reduce the amount of light absorbed inside the sign.
   b) Require that internally illuminated signs use opaque backgrounds, reducing the total amount of illumination required for a legible message at night.
   c) Assume top lighted externally illuminated signs, which will reduce the luminaire dirt depreciation factor considerably, allowing for more light output over the life of the lamp.

Recommendations

Definitions

Externally Illuminated Sign	Any sign that is lit by a light source that is external to the sign.
Internally Illuminated Sign	A sign with an internal light source where the message area is luminous.

[8] Dirt accumulation is important for outdoor luminaires in California, which has little rain for six months of the year.

Panel Sign	An internally illuminated sign built in a regular shape, with a continuous translucent message panel.
Channel Sign	An internally illuminated sign with multiple components, each built in the shape of an individual letter or symbol, with a separate translucent panel over the light source for each element. The completed sign consists of an assemblage of individual letters or symbols, each independently illuminated.
Unfiltered Sign	An internally illuminated sign where the viewer perceives the light source directly as the message, without any colored filter between the viewer and the light source. Examples include simple neon, cold cathode, and LED signs.
Sign Area:	The illuminated area of the sign. The area of a panel sign includes all the area of the message panel. The area of a multifaceted sign is calculated at 90° to each face or planar surface.
Lighting Power Density (LPD)	The connected load of the illumination sources for a lit sign, divided by the area of the sign, expressed in W/ft^2. A signboard with a message on both front and back has twice the area of a sign facing one direction.

Provisions

1) Any illumination source greater than 5 W used for any outdoor sign shall have a minimum efficacy of 25 MLPW.
2) Any illuminated outdoor sign, with a total connected load of more than 20 W per face, shall have a photocell or astronomical timer to insure it is turned off during the daytime, and a timeclock control to insure that it can be turned off after curfew. These control requirements are in addition to the control requirements in Section 131(f).
3) Any outdoor sign which is illuminated during the daytime must be supplied with a control that will enable it to be dimmed to at least 50% of light output at night.
4) Illuminated signs with a connected load of more than 20 W per face will not be allowed in LZ1.
5) Externally illuminated signs shall use light sources with a minimum efficacy of 55 MLPW, and have a maximum lighting power density as calculated according to Table 35 below.
6) Internally illuminated panel signs shall met the following conditions:
   a) The light source shall be greater than 70 MLPW.
   b) The message area of the sign, as expressed in letters or symbols or images, shall be constructed of translucent material, while the background of the sign, and all enclosing structures, shall be opaque.
   c) All interior surfaces surrounding the light source, with the exception of the translucent message area, shall be constructed of highly reflective material, with a surface reflectance of 80% or greater.
7) Internally illuminated channel and unfiltered signs shall met the following conditions:
   a) The light source shall be greater than 25 MLPW.
   b) The message area of the sign, as expressed in letters or symbols or images, shall be constructed of translucent material, while background of the sign, and all enclosing structures, shall be opaque.
   c) All interior surfaces surrounding the light source, with the exception of the translucent message area, shall be constructed of highly reflective material, with a surface reflectance of 80% or greater.

Table 35 – Requirements for Billboards and Signs

		Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
Minimum Source Efficacy	Externally Illuminated Signs	N/A	55 mL/W	55 mL/W	55 mL/W
	Internally Illuminated Panel Signs	N/A	70 mL/W	70 mL/W	70 mL/W
	Internally Illuminated Channel and Unfiltered Signs	Not allowed over 20 W per face	25 mL/W	25 mL/W	25 mL/W
Lighting Power Density (W/ft^2)	Externally Illuminated Signs	Not allowed over 20 W per face	1.00 W/ft^2	2.00 W/ft^2	4.00 W/ft^2
	Internally Illuminated Panel Signs	Not allowed over 20 W per face	4.00 W/ft^2 (T8s @ 24" oc, or 1 per 8 ft^2)	6.00 W/ft^2 (T8s @ 18" oc, or 1 per 5.3 ft^2)	8.00 W/ft^2 (T8s @ 12" oc, or 1 per 4 ft^2)

Exempt Lighting

1) Publicly-owned traffic signs, or emergency information signs.
2) Signs for historic landmarks, where the signage is using historic lighting technology.

Bibliography and Other Research

Alvarez, L. International Darksky Association. Personal conversation. May 2002.

Guisasolla, Pete. Chief Building Official, City of Rocklin, CA. Personal conversation. May 2002.

California Business and Professional Code. Sections 5401 through 5408, and 13421.

California Vehicle Code. Sections 21350 through 21376, and 21466.5.

Dundas, Bill. "Lamps and Lighting: The role of lamp color in sign illumination." Neon & Lighting Channel on "Sign Web." http://www.signweb.com/.

Fletcher, Jan. "Shedding Some Light." Sign Builder Illustrated. March 2002.

Roberts, John. Plans Examiner, County of Humboldt, CA. Personal conversation. May 2002.

Sacramento County Sign Ordinance; Section 335-08 through 335-09.5.

Thielen, Marcus. "LED or Neon? A scientifice comparison. "Neon & Lighting Channel on "Sign Web." http://www.signweb.com/.

Thielen, Marcus. "Neon Visibility: Understanding the basics of light and color creates satisfied clients." Neon & Lighting Channel on "Sign Web" http://www.signweb.com/.

Measure 9 – Public Right of Way Lighting

Description

This measure recommends maximum power for roadway lighting along with controls and shielding requirements. The recommendations are made separately for each of the lighting zones and for each roadway classification: expressway, local, collector, etc. The design criteria are based on IESNA RP-8-00, which is the industry standard. Lighting models were developed for each roadway type and lighting zone to verify that the IESNA criteria is satisfied with the proposed maximum lighting power.

Design Criteria

The Illuminating Engineering Society of North America (IESNA) recommends several methods for roadway and street lighting. These methods are documented in the “Lighting for Exterior Environments” (RP-33-99); the Lighting Handbook, Ninth Edition; and “Roadway Lighting” (RP-8-00). The recommendations contained in “Roadway Lighting” (RP-8-00) are used in this study because they are the most current and most comprehensive. Furthermore, they originated from the IESNA committee with the primary responsibility for roadway and walkway lighting. RP-8-00 is also American National Standards Institute (ANSI)-approved, which means that it represents a consensus of all groups having an interest in roadway lighting. It is the industry standard practice and describes the procedure and performance guidelines for the design of roadway lighting.

Recommendations are provided for several roadway and street classifications, walkways, and bikeways. Classifications are based not only on the type of roadway (freeway, expressway, major, collector, and local), but also refer to the level of pedestrian activity and the potential for conflict with vehicles. Roadway classifications are based on two different sets of vehicular conflicts. The first is vehicle-vehicle conflict, and the second is vehicle-pedestrian conflict. Vehicle-pedestrian conflict is responsible for a disproportionate number of nighttime fatalities, and is therefore of high importance in the design of roadway lighting.

Three levels of pedestrian conflict are defined below. As potential for pedestrian conflict increases, the recommended lighting level values increase.

High	Areas with significant numbers of pedestrians expected to be on the sidewalks or crossing the streets during darkness. Examples are downtown retail areas; areas near theaters, concert halls, and stadiums; and transit terminals.
Medium	Areas where lesser numbers of pedestrians use the streets at night. Typical are downtown office areas; blocks with libraries and apartments; neighborhood shopping areas; industrial areas; older city areas; and streets with transit lines.
Low	Areas with very low volumes of night pedestrian usage. These can occur in any of the cited roadway classifications but may be typified by suburban single-family streets, very low density residential developments, and rural or semi-rural areas.

Roadway type classifications are described below.

Freeway	A divided major roadway with full control of access (i.e., no crossings at grade). This definition applies to toll as well as non-toll roads.
Freeway Class A	Roadways with greater visual complexity and highway traffic volumes. Usually this type of freeway will be found in major metropolitan areas in or near the central core, and will operate through some of the early evening hours of darkness at or near design capacity.
Freeway Class B	All other divided roadways with full control of access.
Expressway	A divided major roadway for through traffic, with partial control of access and generally with interchanges at major crossroads. Expressways for noncommercial traffic within parks and park-like areas are generally known as parkways.

Major	That part of the roadway system that serves as the principal network for through-traffic flow. The routes connect areas of principal traffic generation and important rural roadways leaving the city. These routes are often known as arterials, thoroughfares, or preferentials.
Collector	Roadways servicing traffic between major and local streets. These are streets used mainly for traffic movements within residential, commercial, and industrial areas. They do not handle long, through trips. Collector streets may be used for truck or bus movements, and give direct service to abutting properties.
Local	Local streets are used primarily for direct access to residential, commercial, industrial, or other abutting property. They make up a large percentage of the total street system, but carry a small proportion of vehicular traffic.

There are three different design methods for roadway lighting listed in IESNA RP-8-00: Illuminance, Luminance, and Small Target Visibility. For the lighting models, only the illuminance criteria were calculated. For each roadway classification, the average horizontal illuminance levels in footcandles and the horizontal illuminance average minimum uniformity are stated. The average horizontal illuminance level is the lowest average maintained lighting level that is permitted between a standard grid of poles. The horizontal illuminance average to minimum uniformity is the worst-case uniformity that is permitted between a standard grid of poles. Uniformity ratios lower than this are desired, since it represents more even lighting. An example of this may be a 3:1 uniformity providing more even lighting than a 4:1 uniformity.

Veiling luminance is another term to describe disability glare. RP-8-00 states "stray light within the eye produces a veiling luminance which is superimposed upon the retinal image of the object to be seen. This alters the apparent brightness of any object within the visual field and the background against which it is viewed, thereby impairing the ability of the driver to perform visual tasks." In the lighting models described below, low-glare IESNA "full cutoff" lighting equipment is used such that the disability glare is minimized.[9]

Lighting design criteria for the various roadway classifications are matched with the four lighting zones: LZ1, LZ2, LZ3, and LZ4. See Table 36 below. Low pedestrian conflict is the criteria for LZ1 and LZ2. Medium pedestrian conflict is the criteria for LZ3. High pedestrian conflict is the criteria for LZ4. Since the lighting levels increase as pedestrian conflicts become more likely, the lighting power density will also increase.

[9] The standard does not recommend full-cutoff luminaires, but does recommend cutoff luminaires.

Table 36 – Design Criteria – Roadway Lighting

Lighting Zone	Conflict	Roadway Classification	Average Horizontal Illuminance	Uniformity of Illuminance Average/Minimum Ratio
1	Low Conflict	Local	0.3	6:1
2	Low Conflict	Expressway	0.9	3:1
		Major	0.9	3:1
		Collector	0.6	4:1
		Local	0.4	6:1
3	Medium Conflict	Expressway	1.2	3:1
		Major	1.3	3:1
		Collector	0.9	4:1
		Local	0.4	6:1
4	High Conflict	Expressway	1.4	3:1
		Major	1.7	3:1
		Collector	1.2	4:1
		Local	0.9	6:1
2-4		Freeway Class A	0.9	3:1
2-4		Freeway Class B	0.6	3:1

Lighting Equipment

Pole heights and luminaire wattages typically increase as the width of the roadway increases. The typical pole height and lamp wattages used are based on commonly used combinations and are then adjusted to meet the lighting criteria for the particular roadway classification.

The lamps used for the lighting model described below are all metal halide (MH) lamps. These lamps have slightly lower luminous efficacy than high-pressure sodium (HPS) lamps, and represent the more conservative design approach for lighting power density (LPD). White light sources, like the MH lamp, have a significant benefit in low-light level visibility that researchers are only now beginning to understand. This benefit has not been considered for the model, which results in another conservative layer to the results.

The MH lamps used are standard-output, universal burn (non-position-oriented) lamps, operated with a constant-wattage autotransformer (CWA) ballast, a typical ballast for this type of luminaire. All lamps are operated in the horizontal position. Provided below are the output and energy characteristics for the MH lamps/ballast combinations used for the model.

Table 37 – Lamping Information – Roadway Lighting

Lamp Type	Input Watts	Mean Lumens	Efficacy
150W MH	185	9920	54
250W MH	310	13500	44
400W MH	460	23680	51
1000W MH	1080	86240	80

The luminaires for many roadway lighting systems are placed on arms out from the pole so that they fall directly over the edge of the traveled way. This is important because it enables a maintenance crew to drive a bucket truck underneath and gain access to the luminaire, and it maximizes the efficiency of the lighting system by placing as much light as possible on the roadway surface. All the model lighting calculations are performed with the luminaire at the edge of the traveled way, except for the median mounted system, which is centered in the middle of the roadway and located at a point where a typical Jersey barrier would be located.

The lighting models all use an IESNA Type III distribution "shoe box" luminaire with anodized hydroformed aluminum reflector, flat lens, and full cutoff optics. Type III optics are commonly used for roadway applications.

The distribution of the light from Type III is an asymmetric oblong oval that is parallel to the edge of the road surface. This results in better uniformity on the road surface for a given luminaire spacing.

Hydroformed optics are commonly used in roadway applications, and are moderate in performance and overall quality of light control. Segmented optics are typically the highest quality, followed by hydroformed, and finally refractor optics, which are generally the worst performers.

Lighting Models

The roadway lighting models use typical streetscape cross-sections that are representative of the various road classifications in the IESNA guidelines. Typical roadway design follows general guidelines for width of lanes, number of lanes, and other variables. Table 38 lists the roadway classifications and shows the assumed typical road cross-sections used in this analysis:

Table 38 – Description of Roadways Used in Lighting Models

Lighting Zone	Roadway Classification	Cross Section Description
1	Local – Low Conflict	2@12’ drive lanes, 1@10’ parking lane
2	Expressway – Low Conflict	4@15’ drive lanes, 2@12 ‘breakdown’ lanes (outer), 2@8 ‘breakdown’ lanes (inner), 20’ median, 2@20’ grading zone at edges
	Major – Low Conflict	5@14’ drive lanes, 2@10’ parking lanes
	Collector – Low Conflict	2@12’ drive lanes, 2@10’ parking lanes
	Local – Low Conflict	2@12’ drive lanes, 1@10’ parking lane
3	Expressway – Medium Conflict	6@15’ drive lanes, 2@12 ‘breakdown’ lanes (outer), 2@8 ‘breakdown’ lanes (inner), 20’ median, 2@20’ grading zone at edges
	Major – Medium Conflict	6@14’ drive lanes
	Collector – Medium Conflict	3@12’ drive lanes, 2@10’ parking lanes
	Local – Medium Conflict	2@12’ drive lanes, 1@10’ parking lane
4	Expressway – High Conflict	8@15’ drive lanes, 2@12 ‘breakdown’ lanes (outer), 2@8 ‘breakdown’ lanes (inner), 2@20’ grading zone at edges
	Major – High Conflict	8@14’ drive lanes
	Collector – High Conflict	5@12’ drive lanes, 2@10’ parking lanes
	Local – High Conflict	2@12’ drive lanes, 1@10’ parking lane
2-4	Freeway Class A	8@15’ drive lanes, 2@12 ‘breakdown’ lanes (outer), 2@8 ‘breakdown’ lanes (inner), 2@35’ grading zone at edges
2-4	Freeway Class B	4@15’ drive lanes, 2@12 ‘breakdown’ lanes (outer), 2@8 ‘breakdown’ lanes (inner), 60’ median, 2@50’ grading zone at edges

A typical roadway cross-section is formed, and the length set to accommodate three luminaires down the length. The lighting calculations are performed across the entire traveled way, from one pole to one-half the distance to the next pole, starting at the middle pole. Because of the symmetry and repetition in the lighting system, a small portion will represent the entire lighting design.

There are four methods for lighting roadways that have been employed in this analysis. The first is a *Single Side* design, where all the lights are on one side of the road only. This design is common on small roads where the light from the luminaire will cover the complete width of the road without difficulty.

The second is a *Staggered* arrangement, where the lighting equipment is located on both sides of the road, but the location is staggered up the roadway so that the brightest point of light (directly underneath the luminaire) is away from the nearest bright point from the nearest luminaire on either side. This design approach is common on roads where the width is great enough that the light may not sufficiently cover the entire width of the road from one side only, but the width is not great enough to be able to use a *Paired* arrangement.

A *Paired* arrangement, the third design approach, is where the light poles are located on both sides of the road opposite each other, and the equipment is paired directly across the road. This is typical on large roads where the width is great enough that lighting from both sides is required.

The fourth design approach is the use of equipment mounted in the *Median*. This approach is useful where the median is narrow, or where the two sides of the road are divided by only a Jersey barrier. This approach may have four luminaire heads on the pole to obtain the light level requirements for the particular road classification. Use of median-mounted lights is not practical for road cross-sections with wide medians, or for non-divided roads, or in conditions where the maintenance of the lighting equipment will be hazardous to drivers or the maintenance crews.

A *High Mast* lighting design approach has not been used for the analysis because this approach tends to be a poor solution for roadway lighting in several respects: high mast lighting systems tend to be energy inefficient, have problems with light trespass and light pollution, and can be a cause of significant glare and visibility problems. Table 39 shows the pole heights, lamp types, and pole spacing and layout used for the lighting models.

Table 39 – Description of Lighting Systems for Roadway Models

Lighting Zone	Roadway Classification	Lamp Type	Pole Height	Pole Spacing / Layout
1	Local – low conflict	150w MH	25	150 Single Side
2	Expressway – low conflict	400w MH	40	150 Single Side
	Major – low conflict	250w MH	30	100 Paired
	Collector – low conflict	250w MH	30	210 Staggered
	Local – low conflict	150w MH	25	150 Single Side
3	Expressway – medium conflict	400w MH	50	90 Paired
	Major – medium conflict	400w MH	40	130 Paired
	Collector – medium conflict	250w MH	30	150 Staggered
	Local – medium conflict	150w MH	25	220 Staggered
4	Expressway – high conflict	1000w MH	70	250 Paired
	Major – high conflict	(2) 400w MH	40	160 Paired
	Collector – high conflict	400w MH	35	150 Paired
	Local – high conflict	250w MH	25	220 Staggered
2-4	Freeway Class A	(4) 400w MH	70	270 Median
2-4	Freeway Class B	250w MH	40	110 Paired

The LPD for the roadway is calculated based *only on the traveled way square footage* for each particular roadway cross-section, and covers the area one-half the distance from the pole to the next pole in both directions. This includes breakdown lanes and parking lanes on roads, but does not include the median or grading edges.

The median and right of way boundaries will add significantly to the total area of some roadway cross-sections, and will also affect the overall lighting design of these roadways. In locations where there is a significant median, there may be little or no contribution of light from one side of the median to the other with a perimeter lighting system, which ultimately results in two distinct lighting designs, i.e., one for each side of the roadway.

Calculations

All roadway lighting calculations are performed using LitePro V1.02 Windows by Columbia Lighting, Inc. and Microware Concepts, Inc. LitePro is a lighting calculation program that performs point-by-point lighting calculations of exterior lighting designs based on the specification of the geometry, the luminaire information, and relevant lumen maintenance information for the model. Calculations can be performed for horizontal and vertical illuminance and luminance within a grid, and computation of uniformity ratios are provided for the calculations.

The luminaire dirt depreciation factor (LDD) used for the model is 0.7, which represents a dirty air environment typically found only near manufacturing facilities and in very dusty environments. For most applications this will represent a conservative design approach.

The initial design for each roadway classification was selected based on common pole heights, lamp wattages, and pole spacing used for roadway lighting in an appropriate condition, considering the likely surrounding neighborhood conditions and typical installations in similar conditions. This initial design was then modified based on the results of the calculations until the criteria were met. Table 40 shows the modified designs.

The initial lighting criterion for roadway lighting design is average illuminance. This is met first by adjusting the lamp wattage and pole spacing to meet the guidelines. The *uniformity* (maximum/minimum ratio) criterion is then checked to verify that it is satisfactory. If the uniformity criterion is unacceptable, the spacing is decreased to meet the level established. Uniformity is the most important criterion for roadway lighting, because the uniformity is a reflection on how “bright” and “dark” the roadway appears to a driver.

Table 40 – Roadway Lighting Calculation Results

Lighting Zone	Roadway Classification	LPD Actual	Average Horizontal Illuminance (fc)		Horizontal Illuminance Avg/Min Ratio		Veiling Luminance Max/Avg Ratio
			Criteria	Calculated	Criteria	Calculated	
1	Local – Low Conflict	0.036	0.3	0.5	6:1	5.4	0.4
2	Expressway – Low Conflict	0.041	0.9	0.9	3:1	2.9	0.3
	Major – Low Conflict	0.069	0.9	0.9	3:1	2.0	0.3
	Collector – Low Conflict	0.067	0.6	0.6	4:1	3.8	0.4
	Local – Low Conflict	0.036	0.4	0.5	6:1	5.4	0.4
3	Expressway – Medium Conflict	0.079	1.2	1.2	3:1	1.9	0.3
	Major – Medium Conflict	0.084	1.3	1.4	3:1	3.0	0.3
	Collector – Medium Conflict	0.074	0.9	0.9	4:1	3.2	0.4
	Local – Medium Conflict	0.049	0.7	0.7	6:1	3.4	0.4
4	Expressway – High Conflict	0.054	1.4	1.5	3:1	3.0	0.3
	Major – High Conflict	0.103	1.7	1.8	3:1	3.0	0.3
	Collector – High Conflict	0.077	1.2	1.3	4:1	3.7	0.4
	Local – High Conflict	0.083	0.9	0.9	6:1	3.4	0.4
2-4	Freeway Class A	0.043	0.9	0.9	3:1	2.5	0.3
2-4	Freeway Class B	0.056	0.6	0.6	3:1	2.8	0.3

Recommendations

This measure is proposed as a model standard to be voluntarily adopted by CALTRANS and local California jurisdictions. The recommendations include requirements for lighting controls, maximum lighting power, and shielding of luminaires. Requirements are expressed by lighting zones.

Definitions

Lighting Power Density	The model standard may place prescriptive limits on the amount of power that can be used (W/ft^2) of lighted streets, roadways, walkways, and bikepaths.
Lighting Controls	The model standard may require photocells, programmable time clocks, or yearly astronomical controls to turn lighting off during daylight hours. Other controls may be required to extinguish some or all lighting in specific areas during curfew.
Equipment Specifications	Shielded luminaires may be required by the model standard for certain areas, possibly dependent on environmental zones.

Lighting Power

Table 41 shows the recommended lighting power densities for roadway lighting in the four lighting zones. These values are multiplied times the traveled way area to obtain the maximum allowed lighting power.

Table 41 – Maximum Lighting Power Density for Roadway Lighting (W/ft²)

Road Classification	LZ1	LZ2	LZ3	LZ4
Expressway	0.036	0.041	0.079	0.054
Major	0.036	0.069	0.084	0.103
Collector	0.036	0.067	0.074	0.077
Local	0.036	0.036	0.049	0.083
Freeway Class A	n. a.	0.043	0.043	0.043
Freeway Class B	n. a.	0.056	0.056	0.056

Controls

All luminaires shall be controlled by a photocell.

Shielding

All luminaires greater than 100 W should be of the cutoff type, as defined by IESNA.

Bibliography and Other Research

American Society of Heating, Refrigerating and Air-Conditioning Engineers. ASHRAE/IESNA Standard 90.1-1999, Atlanta, GA: ASHRAE. 1999.

California Department of Transportation. Standard Plans. July 1999 (Revised October 26, 2000). http://www.dot.ca.gov/hq/esc/oe/project_plans/HTM/stdplns-met-new99.htm.

California Department of Transportation. Traffic Manual. Chapter 9, Sections 9-06 through 9-13. http://www.dot.ca.gov/hq/traffops/signtech/signdel/chp9/chap9.htm.

EPRI Lighting Research Office. IESNA/LRO Proceedings on Outdoor Lighting. February 25-27, 2002 (to be published).

Illuminating Engineering Society of North America, RP-8-00 “American National Standard Practice for Roadway Lighting.” New York, NY: IESNA. 2000.

Illuminating Engineering Society of North America. RP-33-99 “Lighting for Exterior Environments.” New York, NY: IESNA. 1999

Illuminating Engineering Society of North America, RP-28-98 “Lighting and the Visual Environment for Senior Living.” New York, NY: IESNA. 1998.

Illuminating Engineering Society of North America. TM-11-00 “Light Trespass Research, Results and Recommendations.” New York, NY:IESNA. 2000.